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FINAL REPORT

Contract No. FA-WA-4345

ALPHA NUMERIC SYMBOL GENERATION EQUIPMENT

September 1965

Project Nos. 121-321-01A and 122-321-01A

SRDS REPORT NO. RD-65-103

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HAZELTINE CORPORATION
HAZELTINE ELECTRONICS DIVISION
LITTLE NECK, NEW YORK

Hazeltine Corporation, Hazeltine Electronics Division
Little Neck, New York
ALPHA NUMERIC SYMBOL GENERATION EQUIPMENT
Prepared by J. F. O'Connor, September 1965
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(Contract No. FA-WA-4345, Project Nos. 121-321-01A and 122-32-101A,

ABSTRACT

Hazeltine has developed and installed two Alpha Numeric Generator equipments in the FAA Atlanta and Indianapolis Air Traffic Control Centers. These equipments have passed all acceptance tests and are undergoing operation testing. These Alpha Numeric Generators electronically label aircraft radar blips on air traffic controller's displays with identity, altitude, vector,speed, and other data. The use of the Alpha Numeric Generators in the ARTS and SPAN air traffic control systems automates former manual functions of the controllers, reduces the necessary communications with aircraft pilots, and minimizes the possibilities of errors in air traffic control. A summary of development problems and test results on the Alpha Numeric Generators is given.

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SECTION I

INTRODUCTION

Hazeltine has completed the development, construction, delivery and installation and final testing of two Alpha Numeric Generators (ANGs) for the Federal Aviation Agency under Contract FA-WA-4345. The first unit, ANG-1, was installed in the ARTS system at the Atlanta, Georgia, Terminal Air Traffic Control Center in August, 1964. System testing activity commenced in October with the ANG POFA Test and was successfully concluded with the Final System Tests in early February 1965. The second unit, ANG-2, was installed in the SPAN system at the Indianapolis, Indiana, Enroute Air Traffic Control Center in November 1964. Integrated system testing commenced in February 1965 and was successfully concluded in July 1965.

This report contains a brief description of the Alpha Numeric Generator System, together with a summary of selected topics and problems involved in the development of logic and circuitry. A description of the test results of both ANGs is also given. Most of the data consists of excerpts from previous Interim Engineering Reports and POFA Test Results Reports. Data from previously unpublished engineering records is also included.

The function of the ANG (See Figure 1-1) is to provide air traffic controllers at the ATC centers with electronically-written formats of aircraft radar blips on their radar scopes. Each format consists of alpha numerics specifying the aircraft identity, altitude, beacon code and other data, together with vectors, leaders, and certain other lines.

Figure 1-2 is a photograph taken at Hazeltine of a scope display generated by the ANG. Radar and beacon video blips and air route map lines, although normally present in air traffic control displays, are not shown. The ANG writes a symbol over each video target, a short leader line connecting the symbol to a format which consists of three lines of alpha numerics. The upper left hand format in the picture reads: Eastern Airlines Flight 740; assigned altitude 310 hundred feet; ascending; actual altitude 255 hundred feet; track no. 27; beacon code 4634. Vector lines are also drawn from the target symbol to show direction of flight and future aircraft position

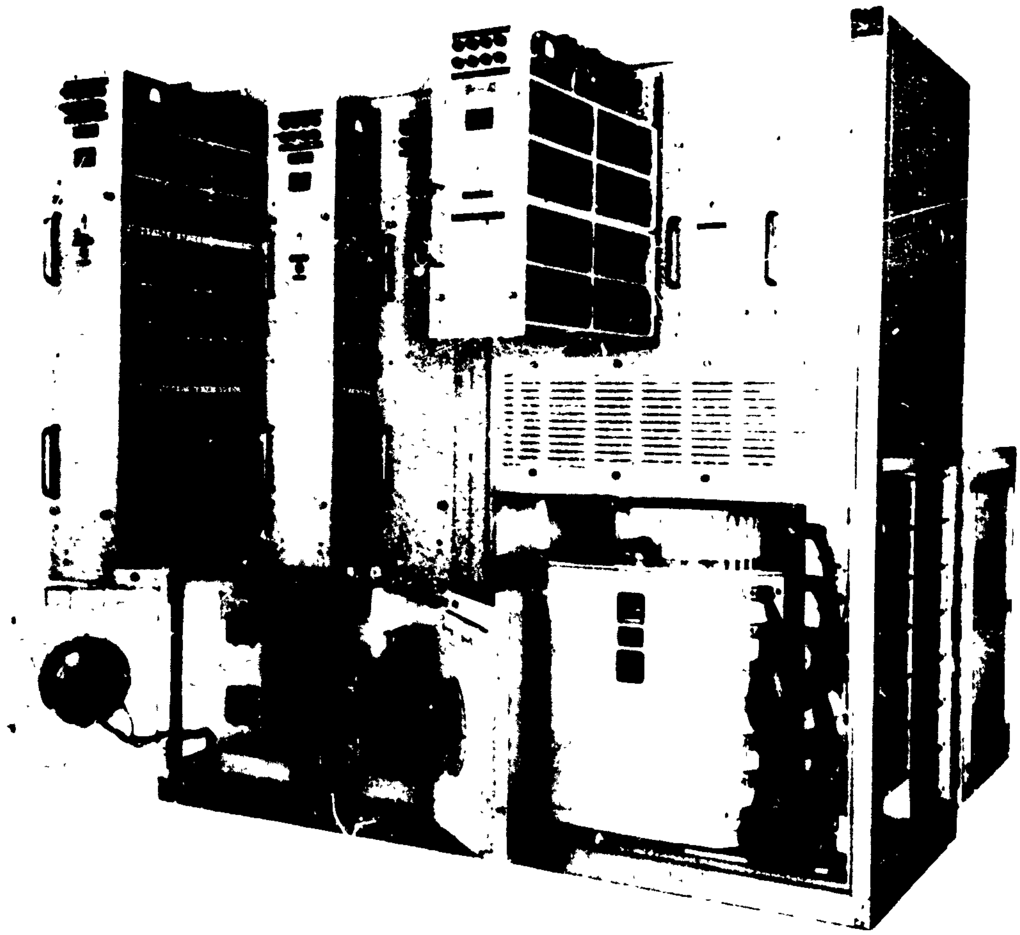


Figure 1-1. Alpha Numeric Generator

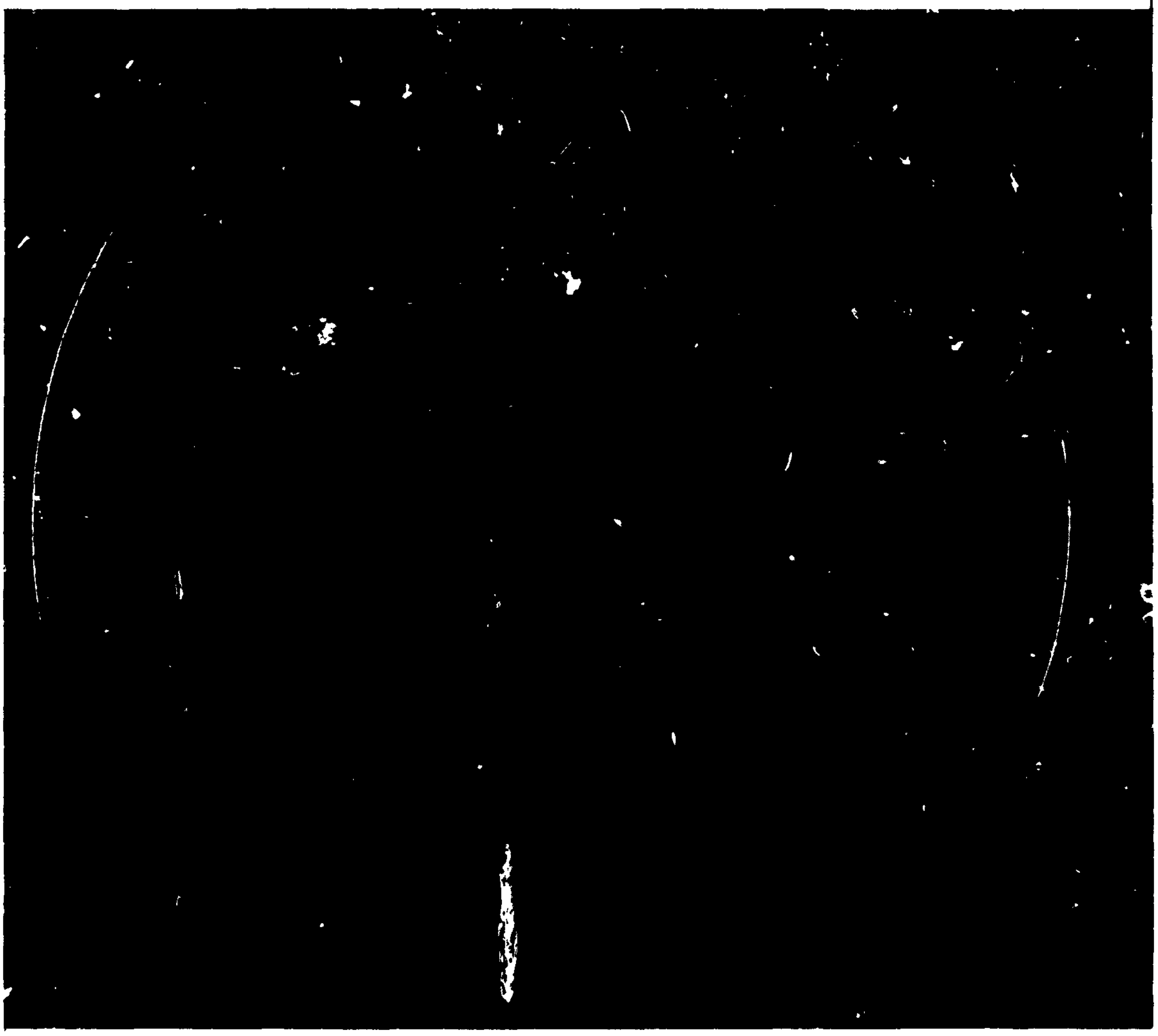


Figure 1-2. Typical ANG Display

at the end of an interval of time selected by the controller. In addition, combinations of full and dashed bars are drawn at the top of some of the formats to indicate certain operating conditions, such as handoff, tracking, emergency, etc. Each ANG provides different alpha numeric pictures for up to 10 different controllers' displays simultaneously.

In the existing method, air traffic control is carried out by direct voice communication between the controllers in the ATC centers and the pilots of the aircraft. Each controller is required to know the exact positions in space of all aircraft under his control, and will issue instructions as necessary to each pilot to fly a course to avoid potential conflicts with other aircraft.

Each controller determines aircraft positions by using previously-filed flight plans to anticipate aircraft arrivals and routes within his sector, together with scope displays of radar and beacon returns to show actual aircraft positions. In addition to the geographical position of each aircraft as shown on the scope, the controller must also know its altitude and identity, the altitude is required to enable potential conflicts to be predicted, and the identity is needed so that the controller can address his instructions to the correct aircraft. At the present time, altitude and identity are obtained primarily from the flight plans. The controller marks identity and altitude on small plastic chips dubbed "shrimp boats," which are placed adjacent to the appropriate aircraft blips on the radar scopes. As the aircraft move across the scopes, the shrimp boats are manually moved to follow them.

The use of the manual methods of marking and following aircraft is subject to errors under certain conditions, such as dense traffic, crossing aircraft tracks on the scope, and handoff of control to another controller when aircraft cross the boundaries of control sectors. An error consisting of associating a shrimp boat with the wrong aircraft can lead to an accident.

To eliminate these errors, the new ATC systems replace the manual shrimp boat method with electronic labelling of each aircraft blip on the radar scope. Each label moves across the scope with its aircraft and remains in position association with it despite track crossings, dense traffic, and handoffs. The label format remains pinned to the aircraft in all sectors controlled by the given ATC center. The content of the format may be changed automatically

or manually by the controller, as aircraft altitude changes, for example. Thus, the type of error associated with the use of shrimp boats is virtually eliminated.

The basic method of obtaining the alpha numeric formats is to add a computer driven, Alpha-Numeric display generator channel to the ATC installation, in parallel with the existing radar and beacon video display channel. The new channel, shown in Figure 1-3, accepts radar $\rho\theta$ video, beacon $\rho\theta$ video, and antenna azimuth. The beacon $\rho\theta$ video includes modes 3/A and C codes of the Air Traffic Control Radar Beacon System (ATCRBS). The new channel assembles all this data into digital codes in x, y geographical coordinates, establishes track histories and predictions, and by means of the ANG converts these signals into TV video which appears as alpha numeric characters, symbols and lines at designated positions on the controllers' radar displays.

In this arrangement all aircraft carrying ATCRBS transponders will automatically have their altitudes and beacon code identities printed on the display adjacent to their video blips. The controllers can also insert additional data in each target format by means of the keyboards provided with the ANG. Alpha numeric data for aircraft not equipped with beacon transponders will be controller-inserted from flight plan data.

The control panels furnished with the ANG also permit each controller to modify his display and other controller's displays for various purposes. Some of these are as follows:

1. From flight plan information each controller can type onto his display, in a video-free area at top or bottom, the formats of all expected aircraft arrivals into his sector.

2. As each aircraft arrives into his sector, the controller can cause each format to be moved out of this "store display" area and pinned to the correct aircraft which it will then follow throughout flight. As each format is taken out of the store display, the remaining formats automatically repack themselves toward the bottom (or top) of the display.

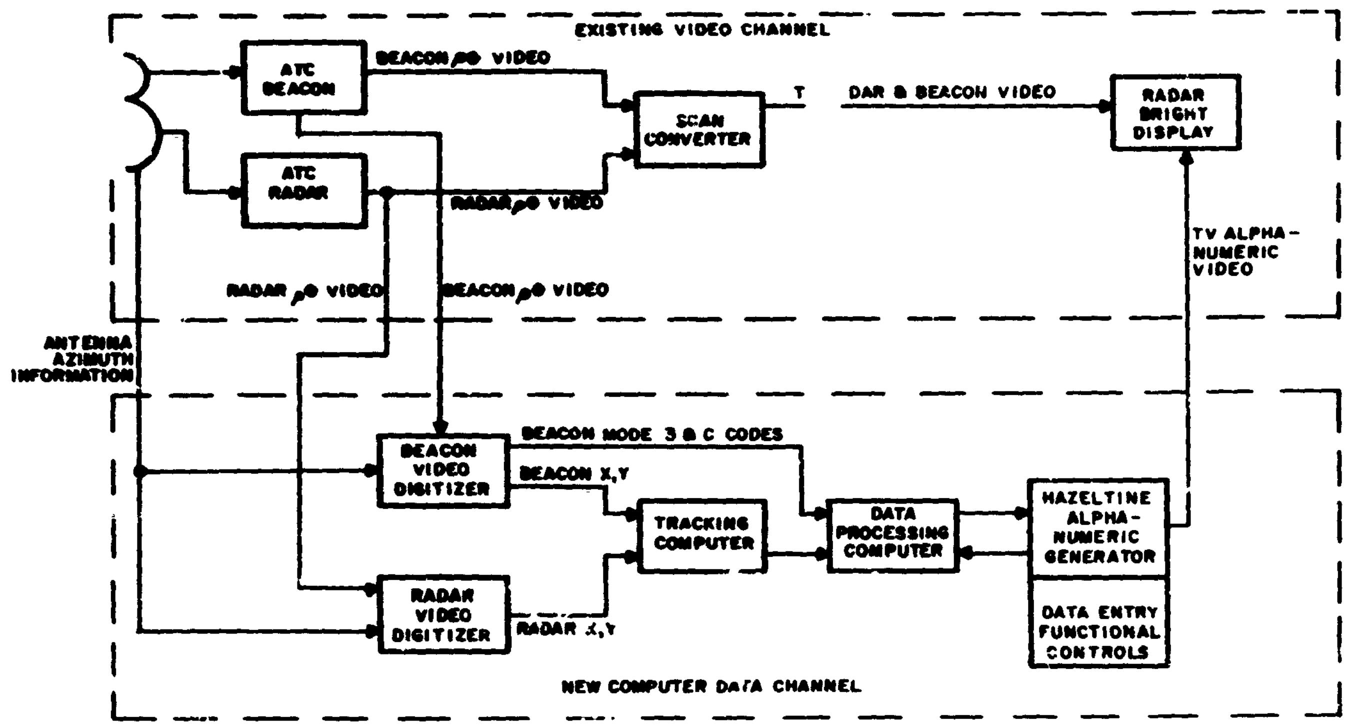


Figure 1-3. FAA ARTS Air Traffic Control System

3. The controller can reposition any or all formats with respect to their targets to eliminate overlapping of formats and other data. The controller can also erase portions of all formats for the same purpose and restore them as needed.

4. The controller can readily make conflict predictions by causing aircraft velocity vectors to be displayed. These vectors indicate aircraft direction and position at the end of a controller-selected period of time (1 to 8 minutes). Also for conflict prediction, each controller can quickly obtain on his display the formats of other aircraft in his sector which are under control of other controllers.

5. Each controller can designate an intended target for handoff to an adjacent controller by inserting an appropriate horizontal bar above that target's format (see Figure 1-2). This bar appears on both controllers' displays. The adjacent controller acknowledges and accepts the handoff by erasing both the bar from his display and the complete format from the first controller's display.

6. The controller can communicate with the Display Processing Computer by means of his control panels to modify computer program routines for his display. He can request any of several kinds of data on any aircraft, can cause them to be tracked by the system, can alert other controllers to take necessary action, and can terminate any operational function.

SECTION II

SYSTEM DESCRIPTION

A. Introduction

The Alpha Numeric Generator (ANG) is a major component of im proved air traffic control systems. The ANG responds to computer-generated instructions and electronically writes aircraft identity, altituc and control information alongside primary or secondary radar returns c RBDE-5 scan converted TV displays.

The Alpha Numeric Generator in an air traffic control system pro vides the operator with a flexible, flicker-free, real time display of computer generated information relative to radar targets which are und his control. The display system also provides the controller with the capability of communicating with the computer to request the display of special data and/or to modify data which is being displayed.

The ANG accepts a series of words from the UNIVAC 1218 Computer. These words define the characters and symbols to be displayed and the coordinates at which they are to appear. The ANG interprets the input message, generates each character and/or symbol in the form of a 5 x 7 dot matrix and stores the selected dots in a magnetic memory from which the characters and symbols are read out to the RBDE-5 TV displays.

The ANG equipment has been constructed in two configurations. One configuration, designated ANG-1, provides six independent TV display channels and is used in the ARTS system; the other configuration, designated ANG-2, is a ten channel equipment for use in the SPAN system.

The Basic System Block and Information Flow Diagram, Figure 2-1, shows ANG-1, the six channel system. The only differences between the ANG-1 shown, and the ten channel ANG-2 are as follows:

(1) The set of input data for the Display Sequencer includes a radar beacon number in addition to the offset and range scale data.

(2) The Display Sequencer receives ten sets of input data from the RBDE-5 instead of six sets.

(3) Ten sets of FCP and Track Ball units are serviced instead of six sets.

(4) Ten sections of the drum memory are used for storing video data instead of six sections.

(5) Ten sets of video generators instead of six sets are required for servicing ten channels.

B. Functional Description

The following paragraphs describe various system components and their roles in the processing of information.

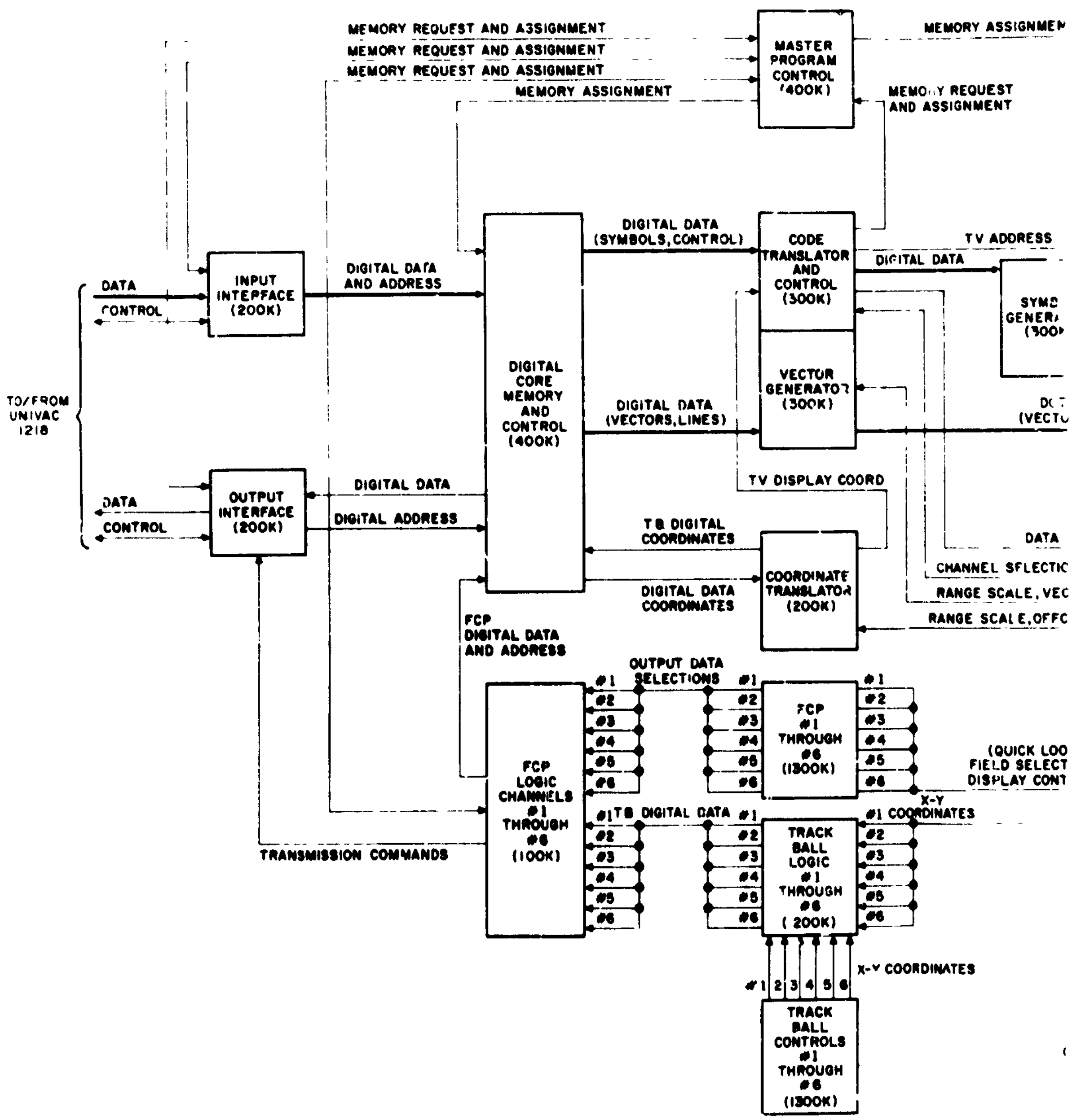
1. Functional Control Panel

The functional control panel (Figure 2-2) consists of a Category/Function selector, an alpha numeric Keyboard and associated control switches. Included in the control switches are field select switches and a quick-look switch. The field select switches control the display of the various portions of the target format, symbol, and leader. The quick-look switch allows selection of other controller-controlled aircraft for display as in the case of adjacent area transfer or coordination. These devices are manually actuated by an operator.

The above items are duplicated for each operator. Simultaneous operation is accomplished by multiplexing the one character output buffer of the keyboard devices to the core memory storage locations.

The data, as composed on the Keyboard or via the Category/Function selection switches, is encoded and stored in a sixteen-bit register associated with each FCP. This register provides storage for one character for the address at which the character is to be stored in the digital memory, and for various command signals. The contents of each FCP register are serially shifted via the keyboard common logic to the digital core memory where they are available for display processing and for transmission to the computer. Data may be entered from each keyboard at a maximum rate of six characters per second.

All of the characters entered by the operator, with the exception of the category and function characters, will be displayed on the operator's monitor within one second after the key depression.


MEMORY REQUEST AND ASSIGNMENT
MEMORY REQUEST AND ASSIGNMENT
MEMORY REQUEST AND ASSIGNMENT
MEMORY ASSIGNMENT
MASTER PROGRAM CONTROL (400K)
MEMORY REQUEST AND ASSIGNMENT
DATA
CONTROL
INPUT INTERFACE (200K)
DIGITAL DATA AND ADDRESS
TO/FROM UNIVAC 1218
DIGITAL CORE MEMORY AND CONTROL (400K)
DIGITAL DATA (SYMBOLS, CONTROL)
CODE TRANSLATOR AND CONTROL (300K)
TV ADDRESS
DIGITAL DATA
VECTOR GENERATOR (300K)
DIGITAL DATA (VECTORS, LINES)
DATA
CONTROL
OUTPUT INTERFACE (200K)
DIGITAL DATA
DIGITAL ADDRESS
TV DISPLAY COORD
TB DIGITAL COORDINATES
COORDINATE TRANSLATOR (200K)
DIGITAL DATA COORDINATES
DATA
CHANNEL SELECTIC
RANGE SCALE, VEC
RANGE SCALE, OFFC
FCP DIGITAL DATA AND ADDRESS
OUTPUT DATA SELECTIONS
FCP LOGIC CHANNELS #1 THROUGH #6 (100K)
FCP #1 THROUGH #6 (1300K)
#1 #2 #3 #4 #5 #6
(QUICK LOO
FIELD SELECT
DISPLAY CONT
X-Y COORDINATES
TB DIGITAL DATA
TRANSMISSION COMMANDS
TRACK BALL LOGIC #1 THROUGH #6 (200K)
#1 2 3 4 5 6
X-Y COORDINATES
TRACK BALL CONTROLS #1 THROUGH #6 (1300K)

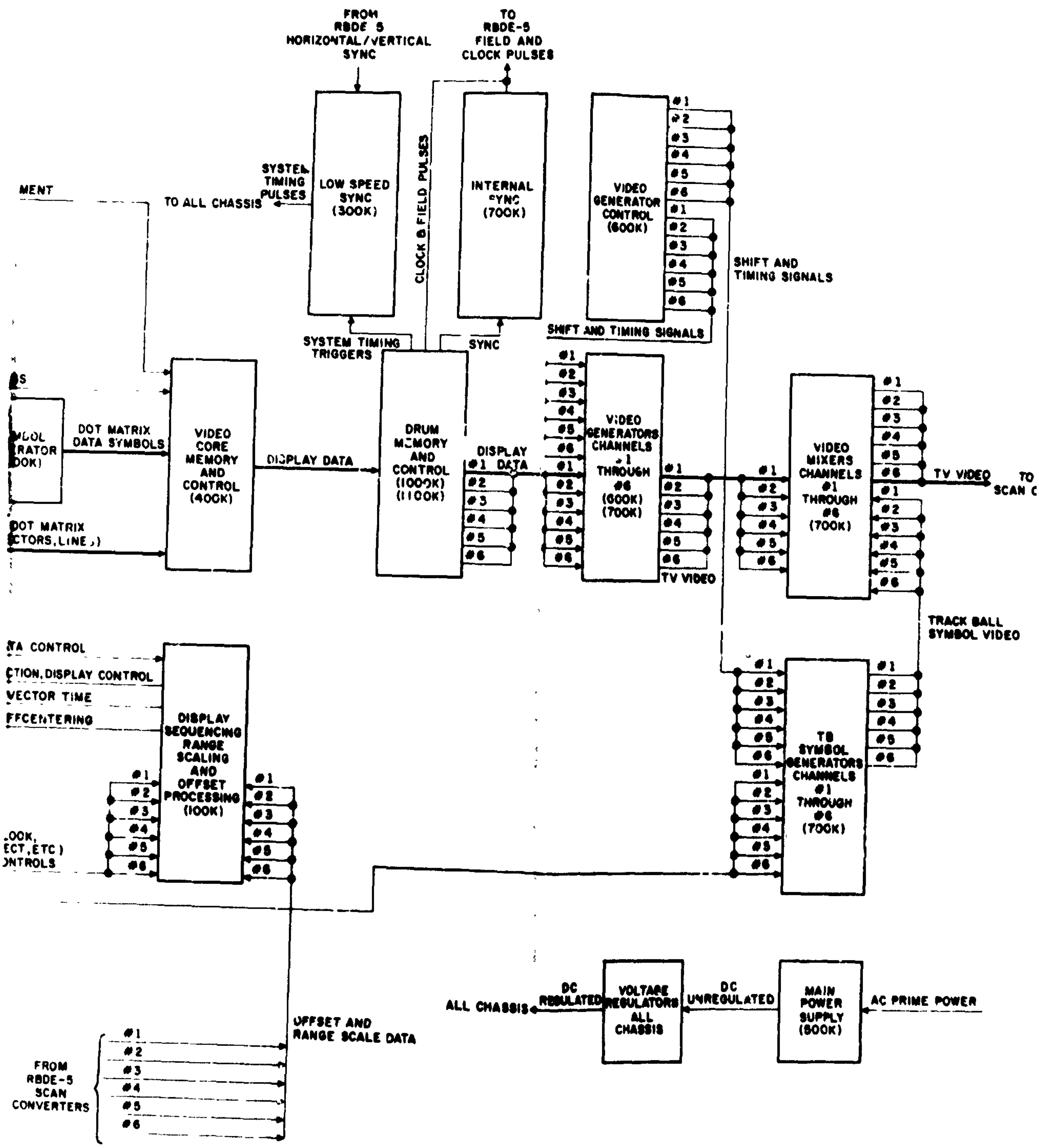
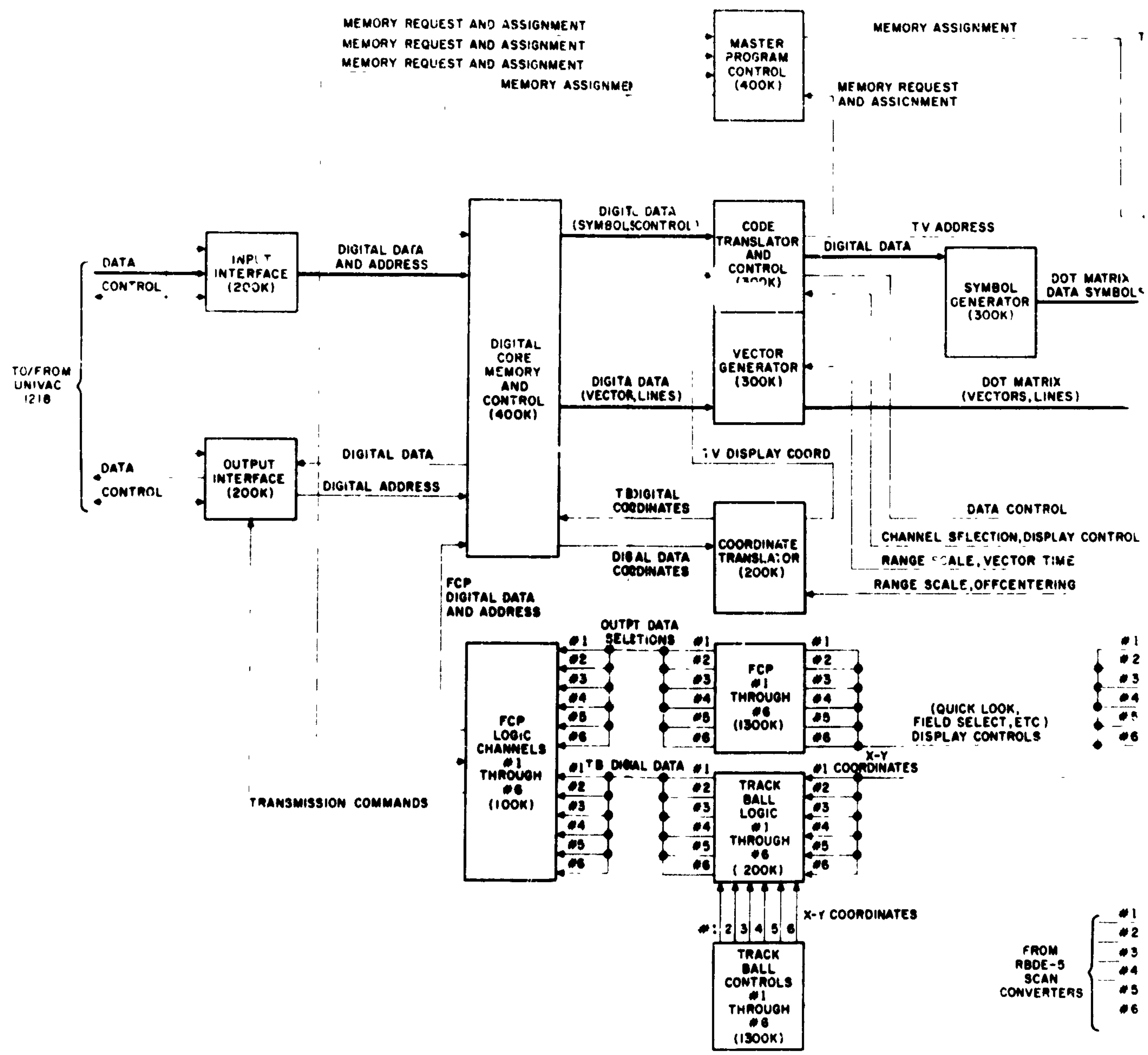


Figure 2-1. Basic System Block and In
Flow Diagram



MEMORY REQUEST AND ASSIGNMENT
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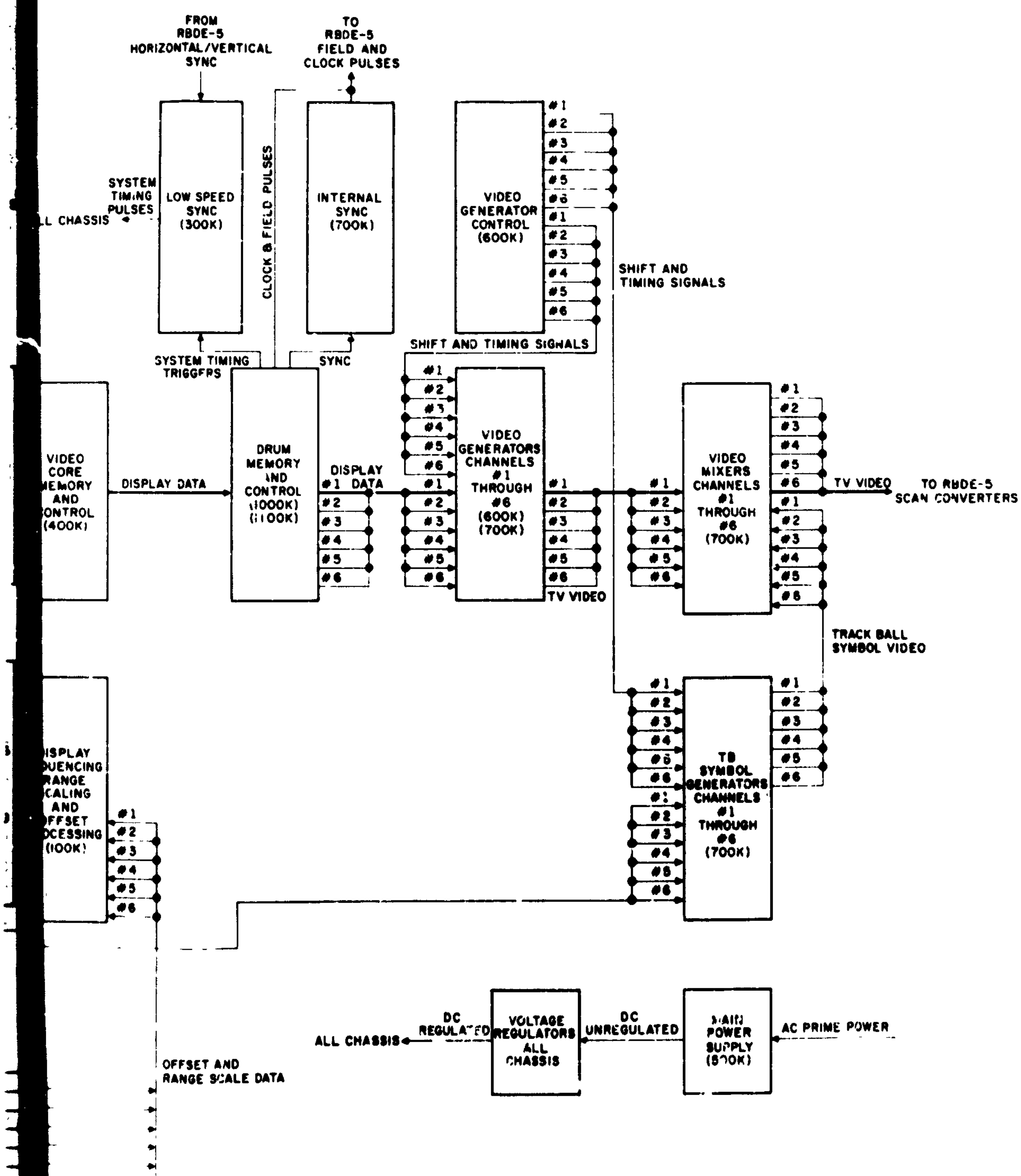
MASTER PROGRAM CONTROL (400K)
MEMORY ASSIGNMENT
MEMORY REQUEST AND ASSIGNMENT
DATA
CONTROL
INPUT INTERFACE (200K)
DIGITAL DATA AND ADDRESS
DIGITAL CORE MEMORY AND CONTROL (400K)
CODE TRANSLATOR AND CONTROL
TV ADDRESS
DIGITAL DATA
SYMBOL GENERATOR (300K)
DOT MATRIX
VECTOR GENERATOR (300K)
DOT MATRIX (VECTORS, LINES)
TO/FROM UNIVAC 1218
OUTPUT INTERFACE (200K)
DIGITAL DATA
DIGITAL ADDRESS
DATA CONTROL
COORDINATE
(200K)
RANGE SCALE, OFFCENTERING
FCP DIGITAL DATA AND ADDRESS
FCP LOGIC CHANNELS #1 THROUGH #6 (100K)
FCP #1 THROUGH #6 (1300K)
(QUICK LOOK, FIELD SELECT, ETC) DISPLAY CONTROLS
X-Y COORDINATES
TRACK BALL LOGIC #1 THROUGH #6 (200K)
TRANSMISSION COMMANDS
X-Y COORDINATES
TRACK BALL CONTROLS #1 THROUGH #6 (1300K)
FROM RBDE-5 SCAN CONVERTERS



FROM
RBDE-5
HORIZONTAL/VERTICAL
SYNC
TO
RBDE-5
FIELD AND
CLOCK PULSES
SYSTEM
TIMING
PULSES
LOW SPEED
SYNC
(300K)
CLOCK & FIELD PULSES
INTERNAL
SYNC
(700K)
VIDEO
GENERATOR
CONTROL
(600K)
SHIFT AND
TIMING SIGNALS
SYSTEM TIMING
TRIGGERS
SYNC
SHIFT AND TIMING SIGNALS
VIDEO
CORE
MEMORY
AND
CONTROL
(400K)
DISPLAY DATA
DRUM
MEMORY
AND
CONTROL
(1000K)
(1100K)
DISPLAY
DATA
VIDEO
GENERATORS
CHANNELS
#1
THROUGH
#6
(600K)
(700K)
TV VIDEO
VIDEO
MIXERS
CHANNELS
#1
THROUGH
#6
(700K)
TV VIDEO
TO RBDE-5
SCAN CONVERTERS
TRACK BALL
SYMBOL VIDEO
TB
SYMBOL
GENERATORS
CHANNELS
#1
THROUGH
#6
(700K)
AND
(100K)
OFFSET AND
RANGE SCALE DATA
ALL CHASSIS
DC
REGULATED
VOLTAGE
REGULATORS
ALL
CHASSIS
DC
UNREGULATED
MAIN
POWER
SUPPLY
AC PRIME POWER

B

Figure 2-1. Basic System Block and Information Flow Diagram

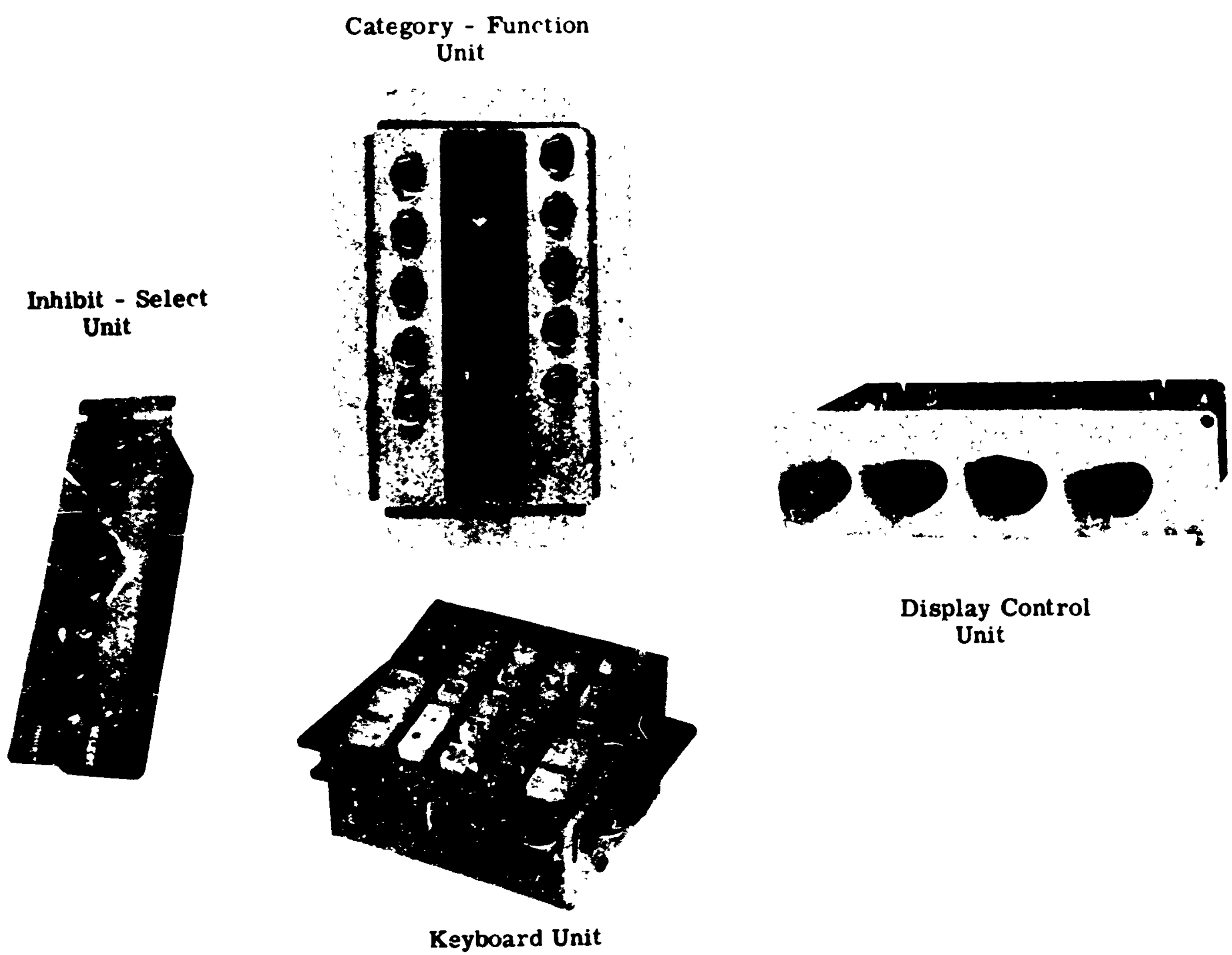


Figure 2-2. Functional Control

Upon ascertaining that the displayed message is correct a depression of the "computer enter" button will cause the data to be transferred from the core memory via the output buffer and interface to the computer.

2. Interfaces

The input and output interfaces accept and provide eighteen-bit words in an asynchronous manner with appropriate controls as described in ARTS Display System Interface Requirements, Univac No. U9002A (revision 1). The input interface stores the eighteen-bit (three character) computer words in the digital core memory. The output interface transmits eighteen-bit words, which have been previously composed on the function control control panels (FCP), from the digital memory to the computer. Each word in this case contains two seven-bit characters, while the remaining four-bits contain no useful information.

3. Digital Core Memory

The input digital core memory has 28 lines of storage. Each line has 128 words of 32-bits each. Each eighteen-bit input word is stored in a thirty-two-bit word slot; thus, if in the future a different computer is used with ANG, words to a maximum length of thirty-two-bits may be accommodated in the existing memory. Three lines (384 words) are reserved for storing the messages composed by the FCP. The remaining 25 lines are used for the storage of computer generated formats. Each of the two hundred format-storage areas can accommodate a maximum of sixteen words.

Acting upon individual service request signals, the master program control sequences the addressing of the core memory by the individual logic blocks.

4. Track Ball

The track ball, shown in Figure 2-3, is used by the controller to include positional information when outputting messages from the ANG to the Display Processing Computer. Manipulation of the track ball causes a visual indication, or slew dot, to move along the console scope in accordance with the direction and amount of track ball movement. The position of this slew dot on the display provides the positional information in the output message to the computer.

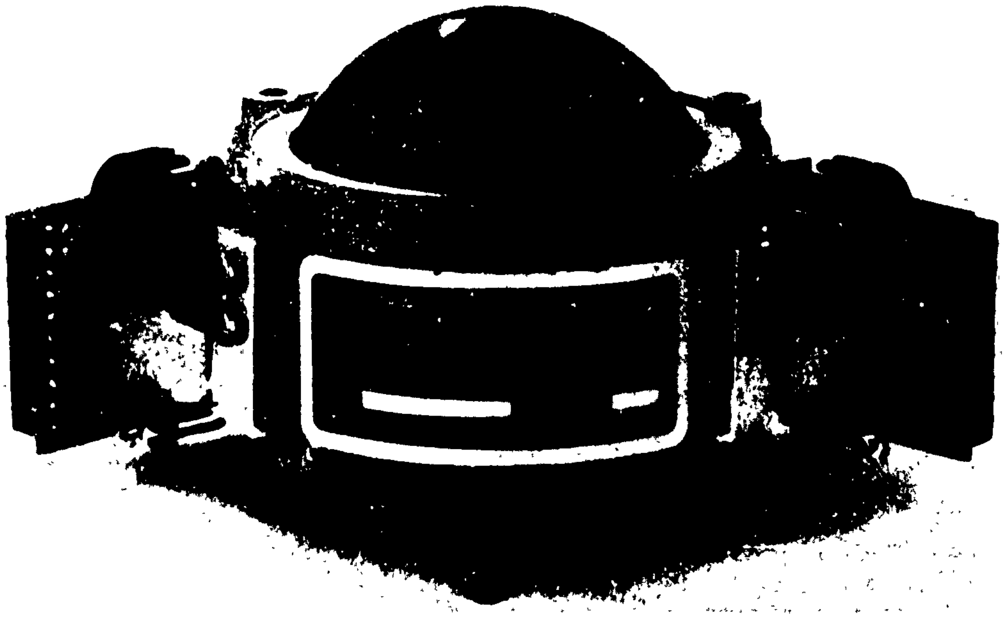


Figure 2-3. Trackball

The rotation of the track ball causes a count to be added to or subtracted from its X and Y registers. The contents of these registers designate the display coordinates at which the slew dot generator is to write the slew dot at a 60 cps rate. When the operator (in the composition of an FCP message) designates that the slew dot coordinates are to be entered as a part of the FCP message, the contents of the associated track ball registers are serially shifted into the keyboard common logic for storage in memory. Simultaneously, a track ball transmit command is presented to the output interface. The output interface in turn commands the coordinate translator to translate these coordinates to either radar X-Y or computer display X-Y coordinates, depending upon the instructions contained in the associated FCP message. At the conclusion of this operation, the FCP message, with the proper coordinates, is transferred to the computer.

5. Display Sequencer

The display sequence logic controls the sequential updating of up to ten displays; the updating is advanced from one display to the next by a command from the code translator. This section also provides the Coordinate Translator with the unique off-center and range data associated with each display.

6. Coordinate Translator

The coordinate transformation logic receives either the radar coordinates associated with the track formats or the display coordinates associated with the display formats from the digital portion of the memory, and converts them to TV X-Y coordinates. In the case of radar coordinates the conversion includes use of the range and off-centered data. The corrected coordinates are then presented to the code translator. The same logic also transforms the trackball TV X-Y coordinates to radar or display X-Y coordinates upon command from the output interface. In this instance the corrected coordinates are stored in the digital memory at the same address in which the original track-ball coordinates were stored.

The coordinate systems used by the ANG 1 and 2 are screen cente orientated coordinate systems defined by twelve bit words for X and Y, each word containing the sign in the MSB position. The following is a definition of the coordinate systems used in the ANGs.

a. Computer Radar Coordinate System is centered about the radar site. It covers an airspace, square in area, measuring approximately 400 by 400 miles with the origin at the center of the square. Positive X axis is to the right and positive Y axis is up. Coordinate data is defined by a 12 bit word with 1/8 mile resolution. One radius off-centering is available.

b. Computer Display Coordinate System has the dimensions $-256 \leq X \leq +256$ and $-256 \leq Y \leq +256$ units with the origin at the center of the TV display. Coordinate data is defined by nine of the 12 coordinate bits. The MSB is 2^8, the LSB is 2^0.

c. Trackball Display Coordinate System has the dimensions $-251 \leq X \leq +251$ and $-200 \leq Y \leq +200$.

d. TV Display Coordinate System has the dimensions of $0 \leq X \leq 512$ and $0 \leq Y \leq 400$ with the origin at the upper left hand corner of the TV display.

7. Vector Generator

Velocity vectors are generated by the system in response to a request message from a controller to the computer. The computer responds by sending vector instructions to the A/N generator system. This information is placed in a definite part of the input message to the ANG. The velocity logic circuits examine the X and Y components and the slope of the velocity vector and calculate the proper memory addresses for the formation of the velocity vector in a dot-by-dot manner. The operator can control the length of the velocity vectors by selecting flying times of 0, 1, 2, 4, and 8 minutes.

8. Code Translator

Data bits for the code translator are received through a buffer register between the digital memory and the code translator. This data consists of address, leader, bar, and character codes. When the address is received, it is loaded into the memory address control.

After the address data has been loaded, any required vectors are first processed, using information obtained from the coordinate and velocity-vector computation section. The processing consists of modifying the TV-XY address in such a manner as to generate the desired vector on a dot-by-dot basis. At the same time, a translation is made from the two-dimensional address of the TV display to a three-dimensional address for storing the resultant dots into the video core memory. In all the functions of the code translator, as described in this paragraph and subsequent paragraphs, the same type of action takes place. Upon completion of the vector, the address registers are returned to the original address for generating the leader .

The leader will be generated like the velocity vector in a dot-by-dot manner, using the vector generation logic. This action continues until a leader of 1, 2, 4, or 8 characters in length is generated. At the completion of this action, the memory address is advanced to the origin of the format, which is dependent upon the leader offset direction and will be such as to maintain the format's origin at a constant distance from the track symbol.

Characters are generated in the following manner. The charact decoder receives a six-bit character code from the input buffer and decodes the data as one of 64 enables. This enable is presented to the character encoder for generating the character or symbol in the desired shape. The shape of the character may be easily changed, even after delivery of the equipment, by simply adding and/or removing diodes on the printed circuit boards.

Th character encoder operates in conjunction with the memory address control to load each group of dots forming the character into the proper location in video core memory. As each character is loaded, the memory control advances to the starting address of the next character. Two dot positions are used for spacing between characters. When the decoder receives a carriage return, line-feed command, the next character is placed at the left-hand edge of the format position, three TV lines below the previous row of characters. In this manner, an entire format is loaded into the video core memory.

9. Video Core Memory

The core memory is a 128 x 128 core array on each of 32 planes. A section of the memory, 28 x 128 x 32, is not required for storing video information but is reserved for use as the input digital memory, and for accumulating messages from the controllers' keyboards.

The video portion of the core memory (100 x 128 x 32) serves as a temporary storage for information in display format. Its high speed capability allows a complete new display picture to be accumulated rapidly. Furthermore, once the information is assembled, it can transfer its entire store of data to the drum tracks of any selected display in one revolution of the drum. The video core memory is then ready to accept information for another display.

10. Magnetic Drum

The magnetic drum contains ten groups of thirty-two tracks each, ten clock tracks and twelve spare tracks. The drum rotates at the synchronous speed of 1800 rpm which corresponds to the TV frame rate. A ten-bit display address is used to select the appropriate display section of the drum for the transfer of data from the video core memory.

Each of the display sections of the drum has associated read heads and amplifiers which supply continuous display information to a video generator.

11. Video Generator and Mixer

The video generator consists of two 32 bit shift registers, control circuitry, and a video clock. One register is loaded in a parallel fashion while the second register is being shifted out serially to provide the video pulses.

The video clock is resynchronized to the drum on each horizontal-drive pulse time. The alternate loading actions of the two 32-bit shift registers are also synchronized to the drum. Two video-output coaxial connectors are provided on each of the video generators. One output is fed to the RBDE-5 video mixer while the second one is available for connection to the maintenance monitor.

A two-channel video mixer is supplied for each TV output to non-additively combine the video from the associated track ball symbol and video generator.

12. Master Clocks

The master clocks accept clock pulses from multiple tracks on the drum and provide for the distribution of these pulses throughout the system. The existing RBDE-5 TV synchronizer is supplied with master timing signals from a portion of these tracks to assure perfect synchronization with the 30 cps rate of the magnetic drum.

C. Physical Description

The alpha-numeric generator is contained in two steel cabinets as shown in Figure 1-1. One cabinet houses the common equipment and the power supply for the system. The other cabinet contains the magnetic drum, its related printed circuit boards and the video generators.

The lower portion of the common equipment cabinet contains the power supply rectifiers, transformers, fuses, and contactors with the cooling fans and filters mounted on the front doors.

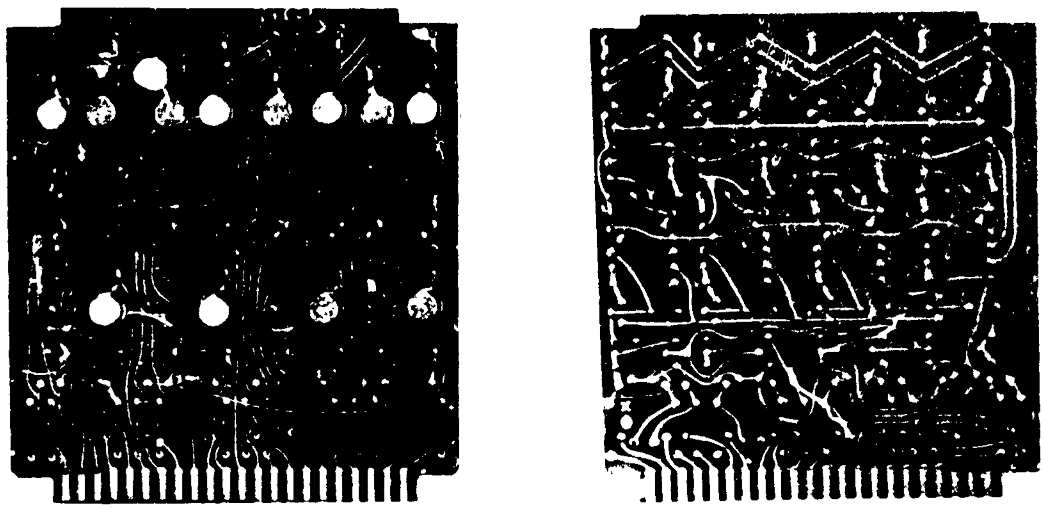
The magnetic drum is mounted on casters so that it may be rolled in and out of the drum cabinet for maintenance purposes. A hinged printed circuit board chassis frame is mounted on the lower right side containing the associated drum electronic circuits.

All electronic circuits, except for the power supplies, are mounted on plug-in printed circuit cards approximately 4.5 inches square. These cards are supported in vertical frames (drawers) which may be extended from the cabinet, while in operation, for maintenance and adjustments.

Each type of card is uniquely keyed so that it can be inserted only in its proper location on the chassis. This is accomplished by keying the connectors and providing mating slots on the cards at the connector end. A simple pulling tool inserted in holes at the top end of the card enable ready removal from the card connector. A "card puller" is provided with the system. Also, extender cards utilized for system testing are furnished. Figures 2-4 and 2-5 illustrate a few of the cards.

Other physical parameters include:

Height	83.5 in.
Width	88.25 in.
Depth	37.1 in.
Weight	3254 lbs
Floor loading	114 lbs/sq. ft.
Power	Approx. 4 Kw
	208V, 3 phase, 60 cycle



Nor/Nand Gates #2-1 (103437)

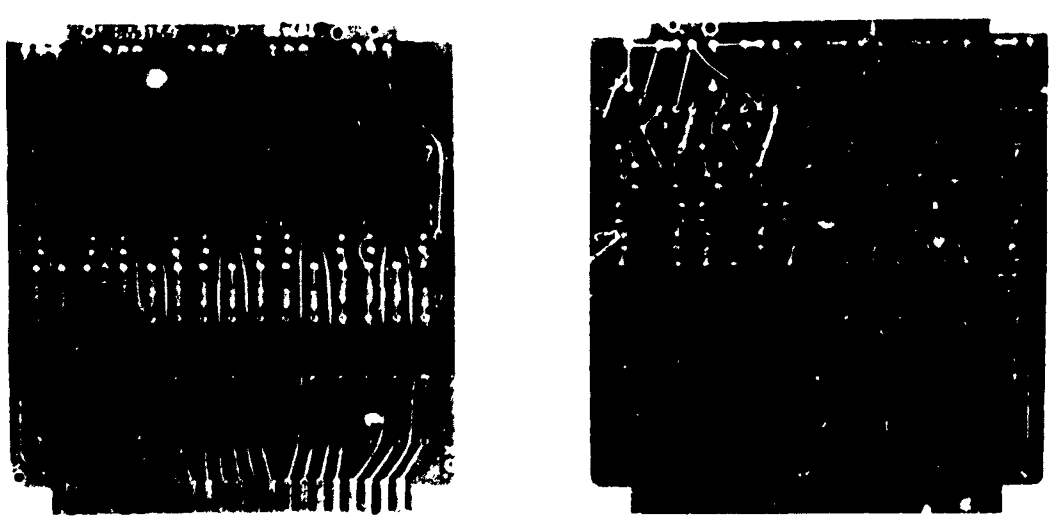
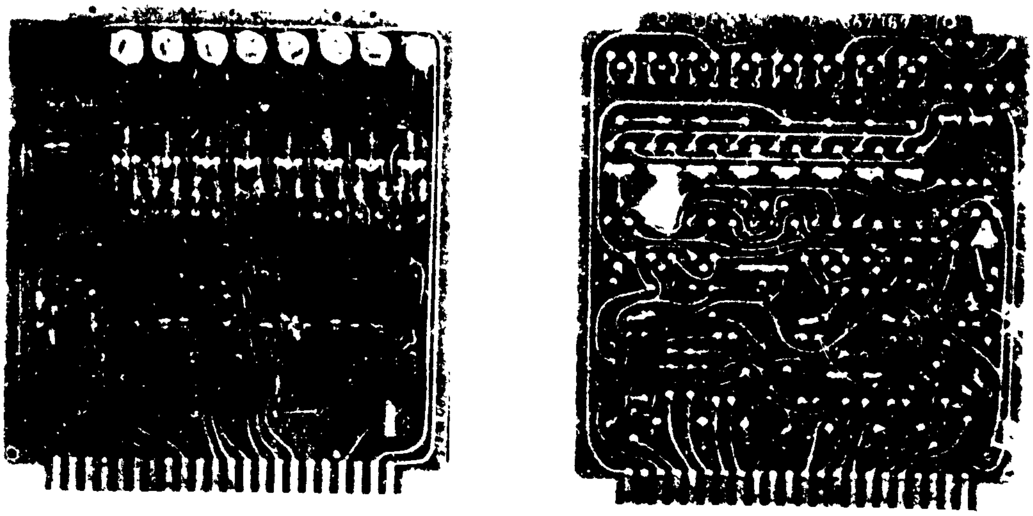
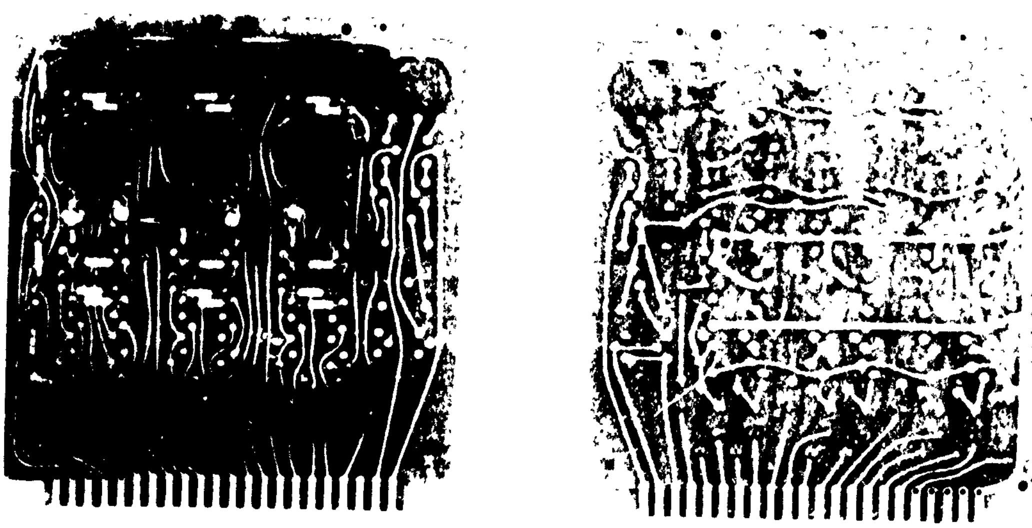


Figure 2-4. Typical Printed Circuit Boards



Counter Encoder (103392)



Hi Speed Register (2) (103440)

Figure 2-5. Typical Printed Circuit Boards

SECTION III

DEVELOPMENT OF SYSTEM AND EQUIPMENT

A. Introduction.

This section consists of a summary of selected engineering topics and problems pertinent to the development of the ANG system, logic, and circuits. It is derived from previous Interim Engineering Reports and unpublished engineering records. Its purpose is to highlight some of the problem areas and solutions unique to the functions performed by the ANG. Some familiarity by the reader with the principles involved in the design of ANG is assumed, since the theory of operation is adequately described in other reports.

The topics are broadly classified into four groups: logic, circuits, system interfaces, and test procedures.

B. Logic

Under this heading are grouped seven topics: two covering the FCP unit and common logic flow, two pertaining to trackball logic and errors in slew dot positioning, one describing a problem in core memory addressing logic, one describing the console identity patching facility and one describing and explaining the use and elimination of the 64 second minute.

1. FCP Unit Flow Chart

The selection of any key on the keyboard, other than right or left alpha, or on the Category-Function module will initiate the generation of an FCP word. A right or left alpha key depression will either set a right or left bar condition or it will generate a reset space bar condition (cleared key) if the other alpha had been depressed previously. See Figure 3-1.

If the first action after a clear keyboard signal is a keyboard key depression, the X and Y display coordinate bits, which determine the position of the validity display on the screen are strobed into shift register positions 7 and 8 and the word counter set to 3 to load the selected character and prepare for the next character.

If it is not the 1st character, a check is made for any of the transmit or erase functions and the corresponding shift register (SR) stage is set if any is present. If the word count for a track ball enters is greater than 12, the overflow condition is set. This causes the error light to be lit which requires an error clear

signal to be generated.

If the key is not an enter or erase command, and the back-space key has not been pushed, the word counter is advanced and the word is strobed into the shift register. If an A/N character was selected along with a right or left alpha, the word is conditioned accordingly. A character count of 14 will cause an overflow condition.

The Z bit, which determines the position of the character on its particular line in memory is strobed into the SR together with the word counter bits.

If the key has not been a transmit or erase entry, or if it has and there are no transmit or erase inhibits, the SR is fed serially into the common logic SR upon application of the sequencer gate, for the particular FCP, and shift gate 1. It is not shifted if an overflow condition has occurred.

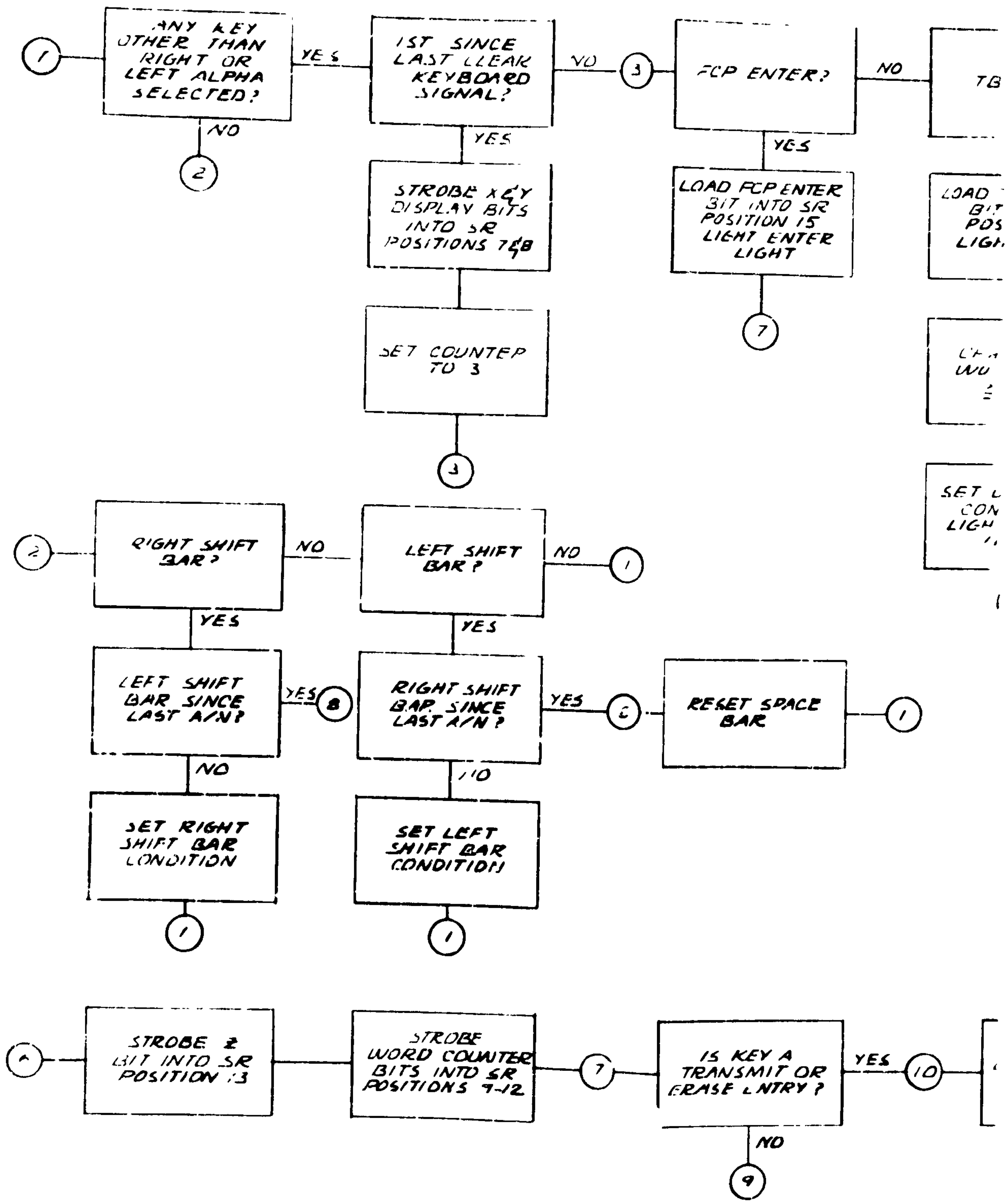
2. FCP Common Logic-Flow Chart (See Figure 3-2)

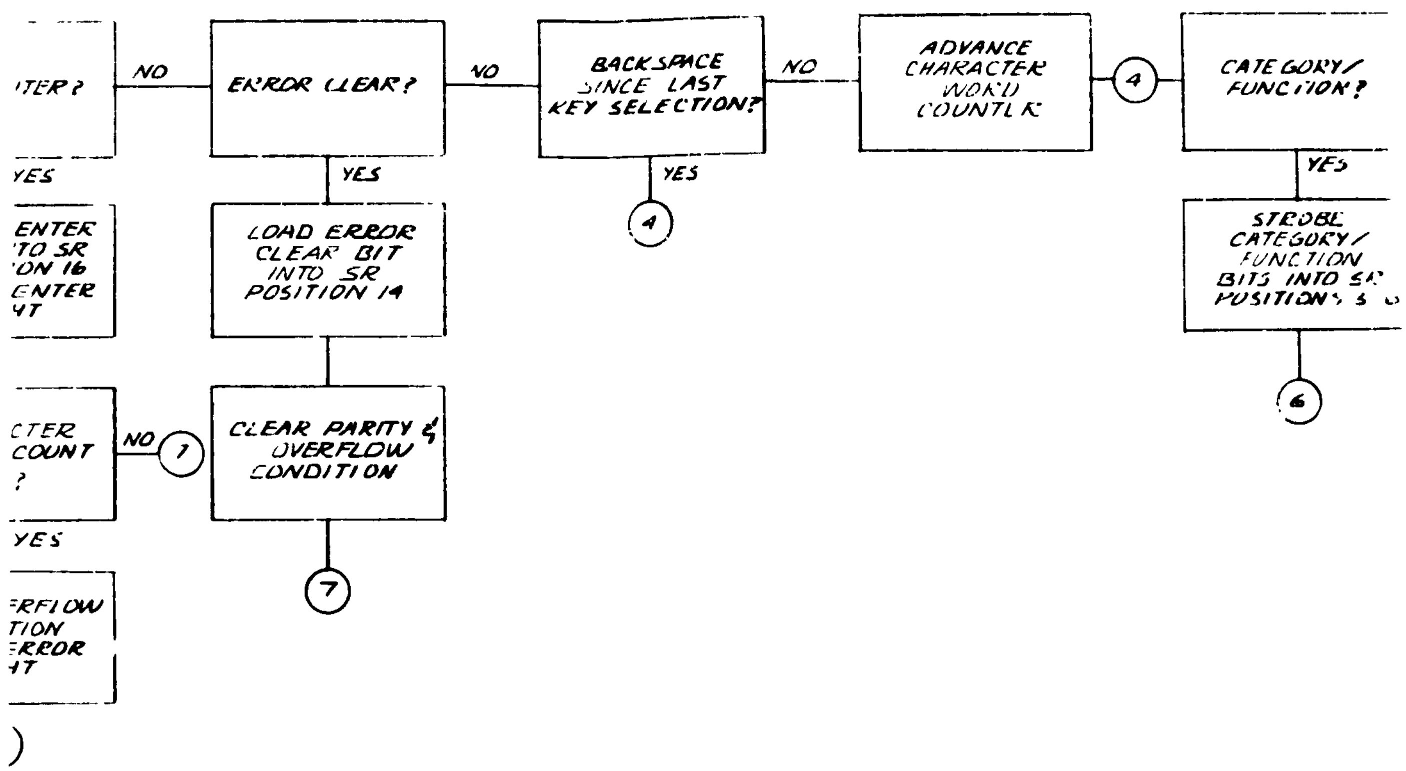
Each vertical sync pulse will advance the console bit counter, selecting each unit FCP in turn. Shift gate 1 will shift the unit logic into the SR at the same time shift gate 3 shifts track ball logic into the X-coordinate and Y-coordinate SR's. Shift gate 2 samples the character part of the word from the unit FCP and sets the parity of it.

At the end of shift time a memory request is sent to the master program control and a transmit or erase command is sent to the I/O if the unit logic calls for one. When a memory request acknowledgement is received, the X and Y coordinates of the desired memory location is sent to the I/O. These coordinates are derived from console counter in the common logic and the character counter from the FCP word.

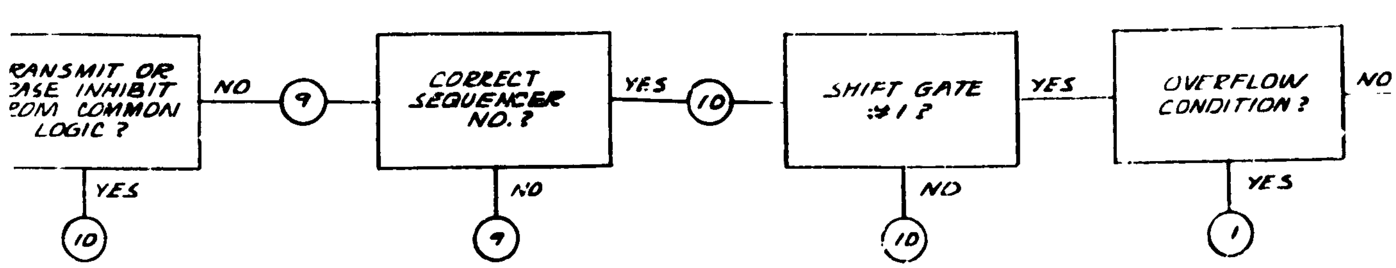
If a TB enter command has not been received and it is not the first character of the format, the A/N character is strobed into memory.

A track ball enter command will cause the character counter to be set to 11 and the distinctive TB enter word to be strobed into memory. The counter is advanced and the TB-X bits strobed into memory, followed by the TB-Y bits. This all takes place

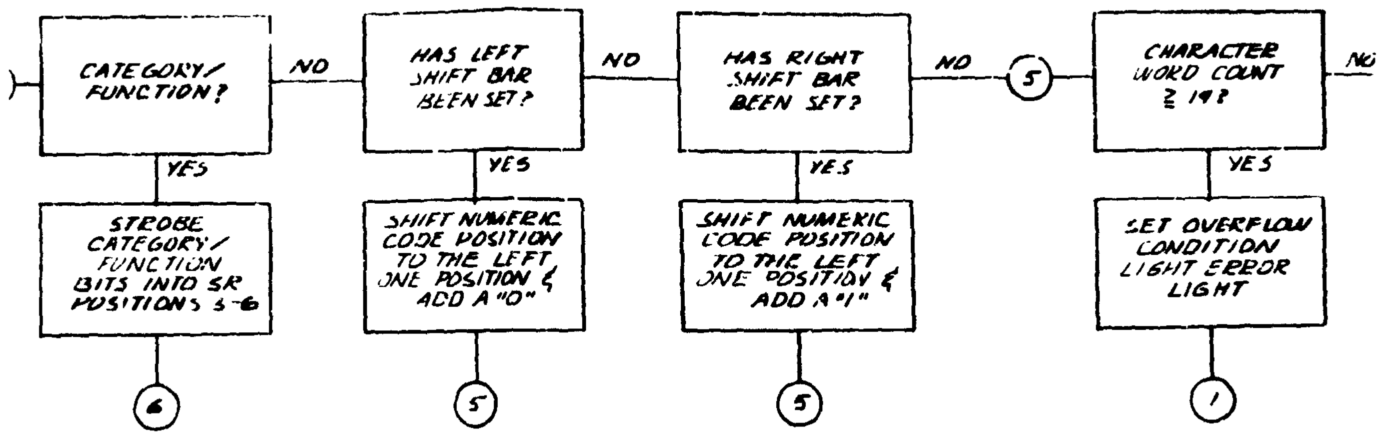

1
ANY KEY OTHER THAN RIGHT OR LEFT ALPHA SELECTED?
YES
NO
2
1ST SINCE LAST CLEAR KEYBOARD SIGNAL?
NO
3
FCP ENTER?
NO
TB
YES
LOAD FCP ENTER BIT INTO SR POSITION 15 LIGHT ENTER LIGHT
7
YES
STROBE KEY DISPLAY BITS INTO SR POSITIONS 7&8
SET COUNTER TO 3
3
2
RIGHT SHIFT BAR?
NO
LEFT SHIFT BAR?
NO
1
YES
YES
LEFT SHIFT BAR SINCE LAST A/N?
YES
8
RIGHT SHIFT BAR SINCE LAST A/N?
YES
6
RESET SPACE BAR
1
NO
NO
SET RIGHT SHIFT BAR CONDITION
SET LEFT SHIFT BAR CONDITION
1
1
STROBE 2 BIT INTO SR POSITION 13
STROBE WORD COUNTER BITS INTO SR POSITIONS 9-12
7
IS KEY A TRANSMIT OR ERASE ENTRY?
YES
10
NO
9



ITER ?
NO
ERROR CLEAR ?
NO
BACKSPACE SINCE LAST KEY SELECTION?
NO
ADVANCE CHARACTER WORD COUNTER
4
CATEGORY/ FUNCTION ?
YES
YES
YES
YES
ENTER TO SR ON 16 ENTER
LOAD ERROR CLEAR BIT INTO SR POSITION 14
4
STROBE CATEGORY/ FUNCTION BITS INTO SR POSITIONS
CTER COUNT ?
NO
7
CLEAR PARITY & OVERFLOW CONDITION
6
YES
7
RFLOW TION ERROR



RANSMIT OR CASE INHIBIT FROM COMMON LOGIC ?
NO
9
CORRECT SEQUENCER NO. ?
YES
10
SHIFT GATE #1 ?
YES
OVERFLOW CONDITION ?
NO
YES
NO
NO
YES
10
9
10
1



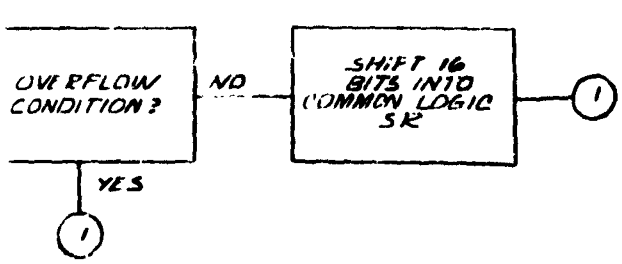
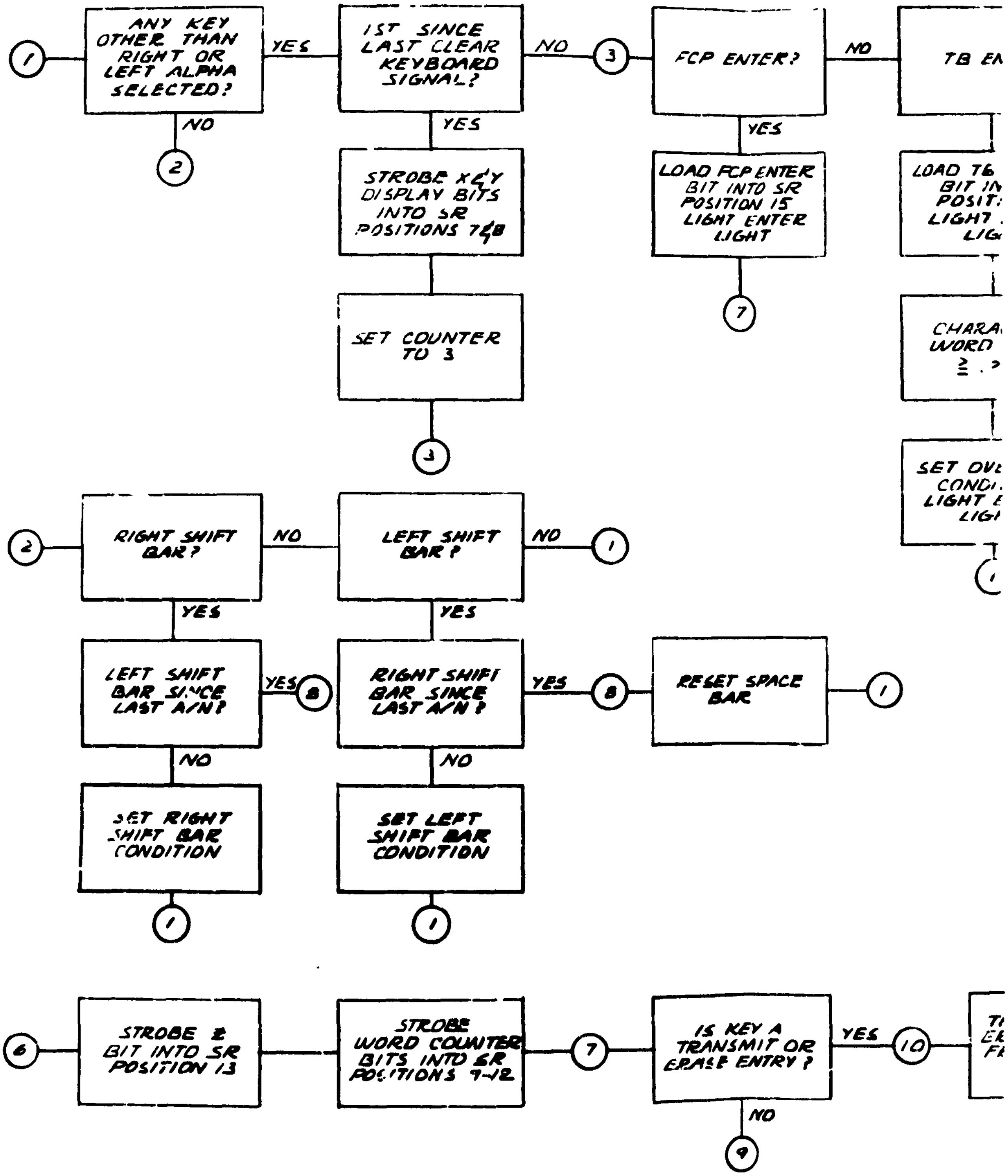


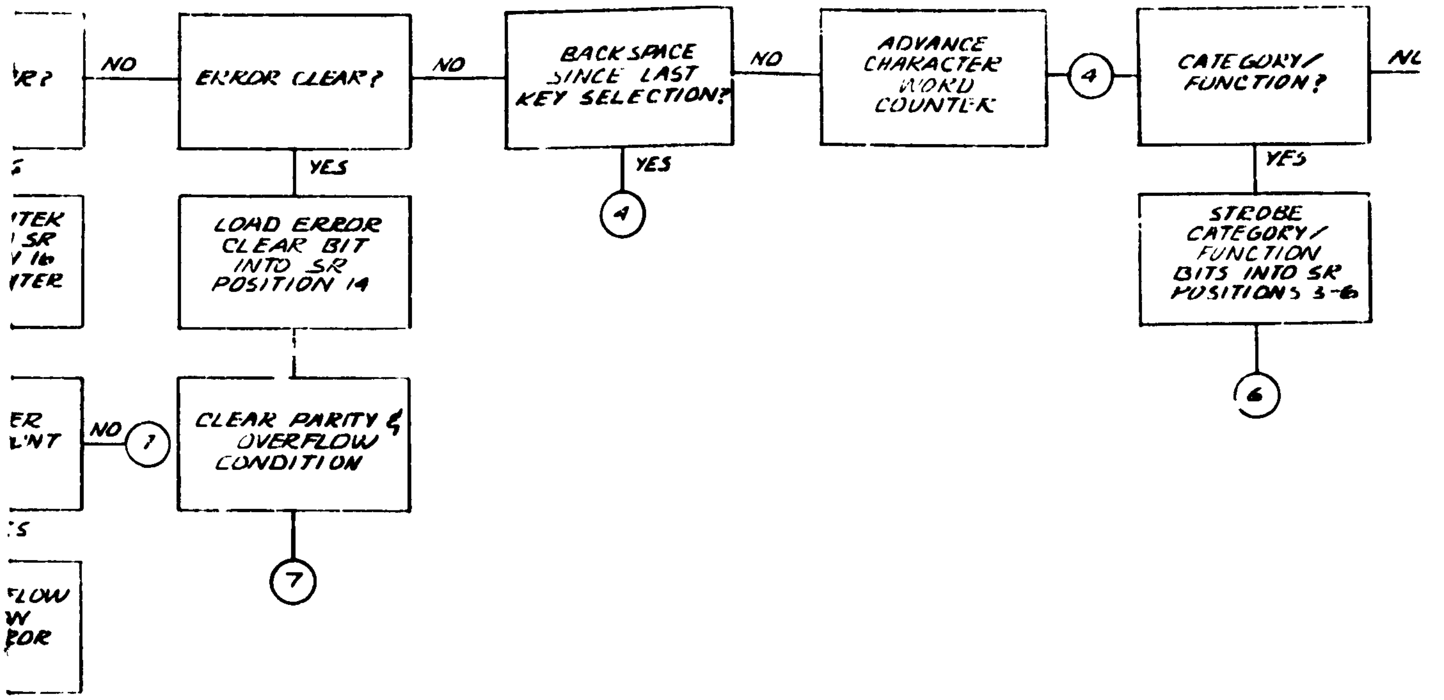
Figure 3-1. Flow Diagram, FCP Unit

Figure 3-1. Flow Diagram, FCP Unit

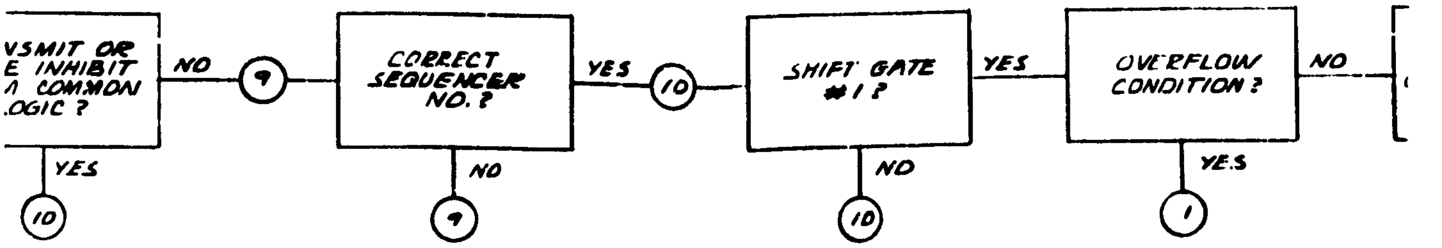


ANY KEY OTHER THAN RIGHT OR LEFT ALPHA SELECTED?
YES
NO
1ST SINCE LAST CLEAR KEYBOARD SIGNAL?
STROBE X&Y DISPLAY BITS INTO SR POSITIONS 7&8
SET COUNTER TO 3
FCP ENTER?
LOAD FCP ENTER BIT INTO SR POSITION 15 LIGHT ENTER LIGHT
RIGHT SHIFT BAR?
LEFT SHIFT BAR?
LEFT SHIFT BAR SINCE LAST A/N?
RIGHT SHIFT BAR SINCE LAST A/N?
RESET SPACE BAR
SET RIGHT SHIFT BAR CONDITION
SET LEFT SHIFT BAR CONDITION
STROBE Z BIT INTO SR POSITION 13
STROBE WORD COUNTER BITS INTO SR POSITIONS 7-12
IS KEY A TRANSMIT OR ERASE ENTRY?

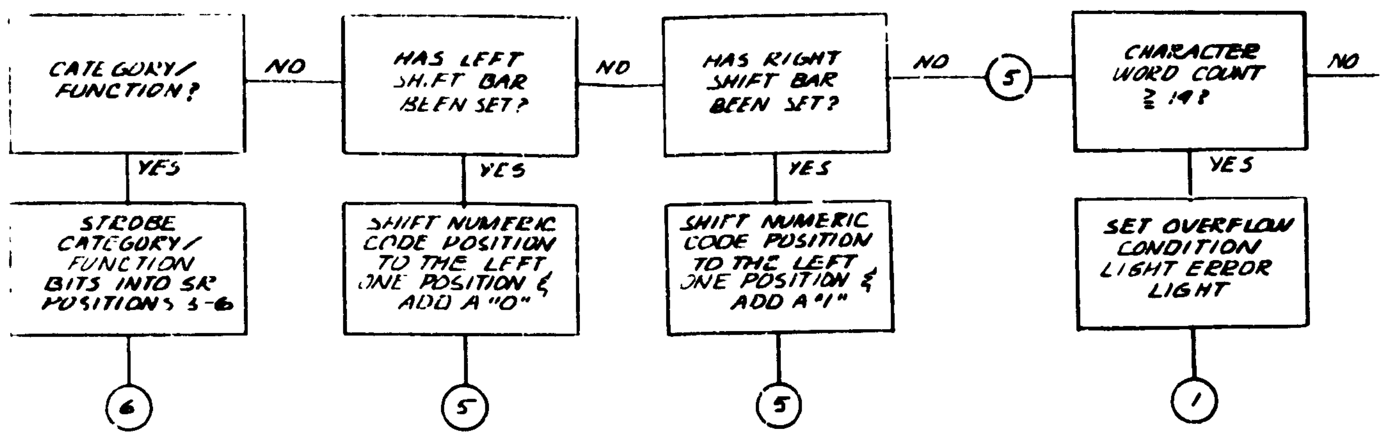
A

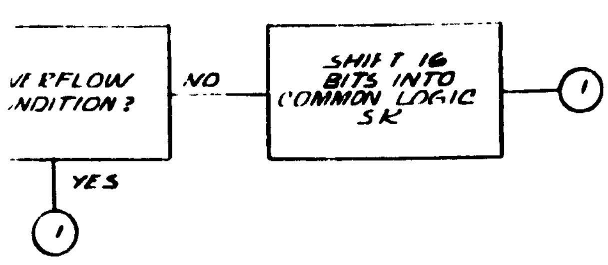


NO
ERROR CLEAR?
NO
BACKSPACE SINCE LAST KEY SELECTION?
NO
ADVANCE CHARACTER WORD COUNTER
4
CATEGORY/ FUNCTION?
YES
LOAD ERROR CLEAR BIT INTO SR POSITION 14
YES
4
YES
STROBE CATEGORY/ FUNCTION BITS INTO SR POSITIONS 3-6
6
NO
7
CLEAR PARITY & OVERFLOW CONDITION
7

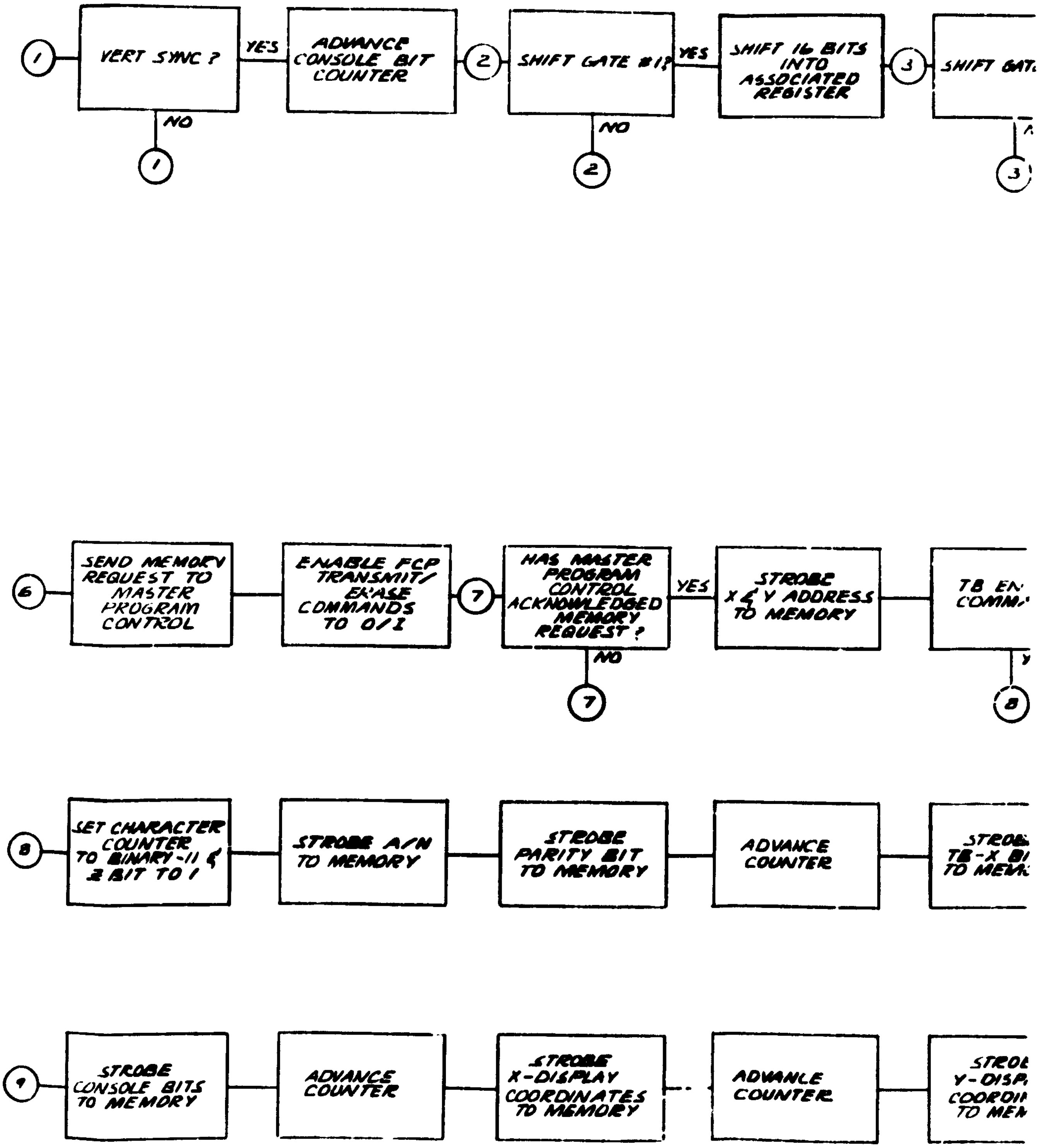


NO
9
CORRECT SEQUENCER NO.?
YES
10
SHIFT GATE #1?
YES
OVERFLOW CONDITION?
NO
YES
10
NO
9
NO
10
YES
1


CATEGORY/ FUNCTION?
NO
HAS LEFT SHIFT BAR BEEN SET?
NO
HAS RIGHT SHIFT BAR BEEN SET?
NO
5
CHARACTER WORD COUNT ≧ 14?
NO
YES
STROBE CATEGORY/ FUNCTION BITS INTO SR POSITIONS 5-6
6
YES
SHIFT NUMERIC CODE POSITION TO THE LEFT ONE POSITION & ADD A "0"
5
YES
SHIFT NUMERIC CODE POSITION TO THE LEFT ONE POSITION & ADD A "1"
5
YES
SET OVERFLOW CONDITION LIGHT ERROR LIGHT
1


NO
SHIFT 16 BITS INTO COMMON LOGIC SR
1
YES
1

C



VERT SYNC ?
YES
NO
ADVANCE CONSOLE BIT COUNTER
SHIFT GATE #1?
YES
NO
SHIFT 16 BITS INTO ASSOCIATED REGISTER
SEND MEMORY REQUEST TO MASTER PROGRAM CONTROL
ENABLE FCP TRANSMIT/ ERASE COMMANDS TO 0/1
HAS MASTER PROGRAM CONTROL ACKNOWLEDGED MEMORY REQUEST ?
YES
NO
STROBE X & Y ADDRESS TO MEMORY
SET CHARACTER COUNTER TO BINARY-11 & 2 BIT TO 1
STROBE A/N TO MEMORY
STROBE PARITY BIT TO MEMORY
ADVANCE COUNTER
STROBE CONSOLE BITS TO MEMORY
ADVANCE COUNTER
STROBE X-DISPLAY COORDINATES TO MEMORY
ADVANCE COUNTER

H

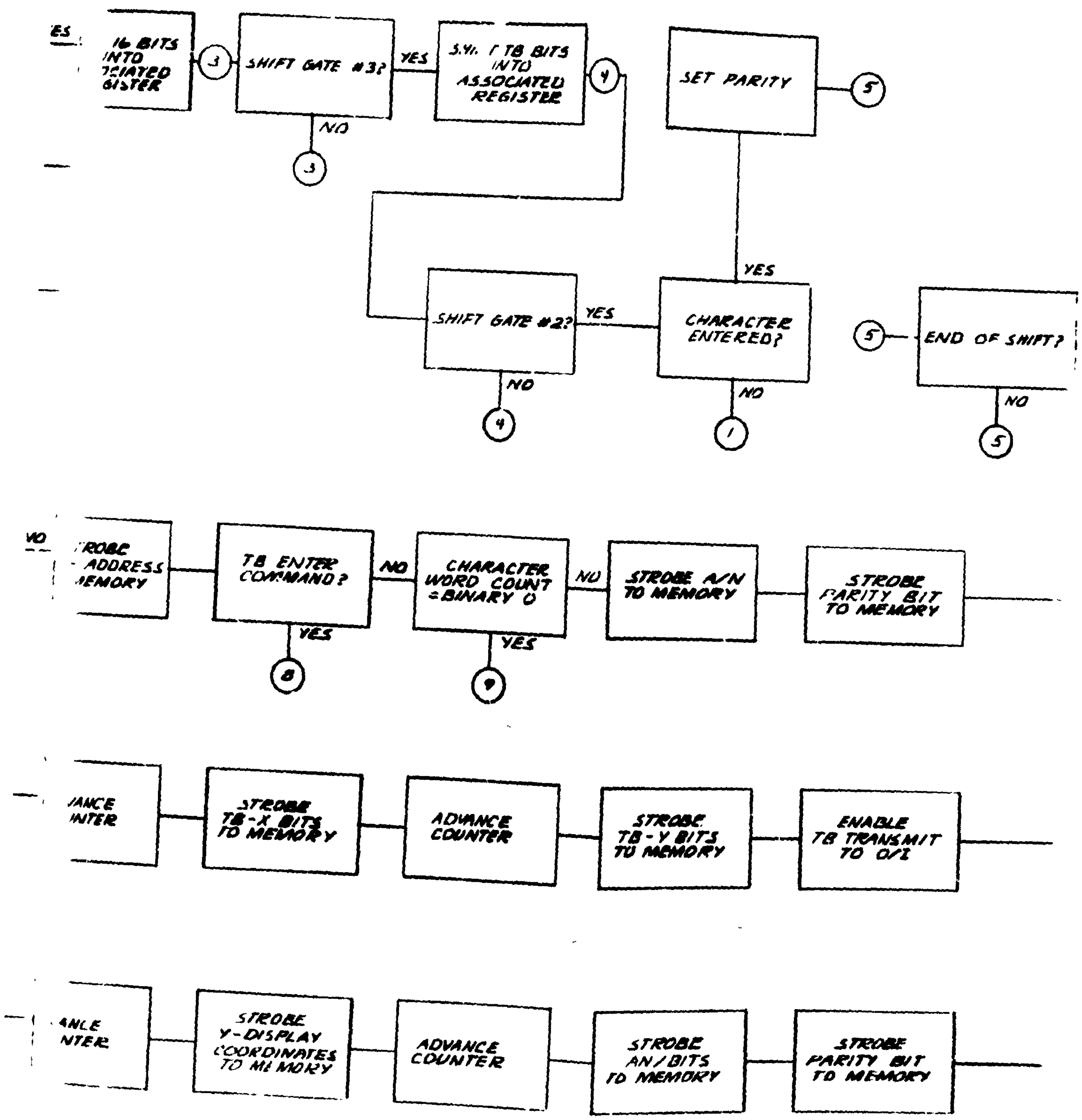
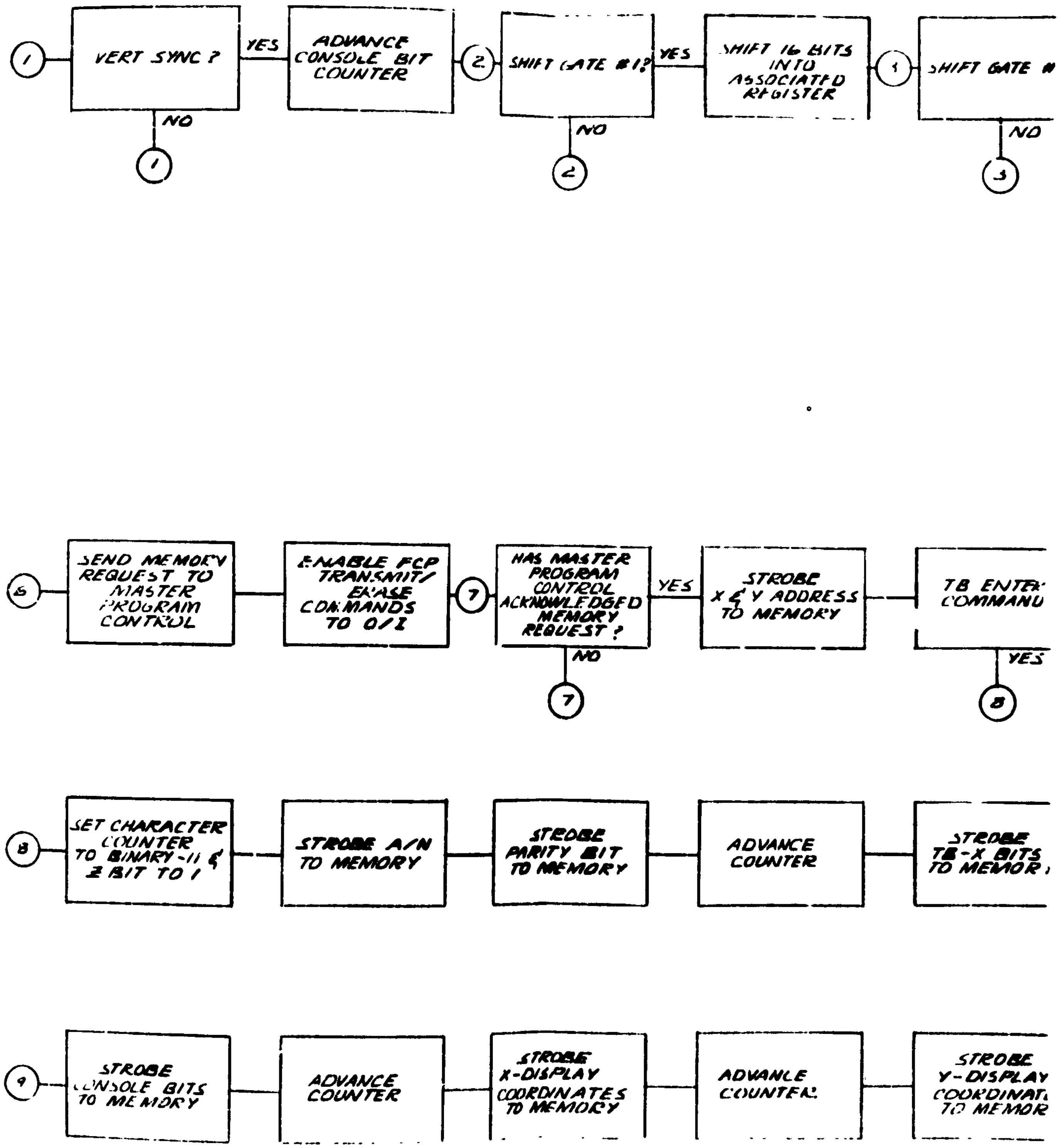


Figure 3-2. Flow Diagram Con Logic (FCP)


1
VERT SYNC ?
YES
NO
1
ADVANCE CONSOLE BIT COUNTER
2
SHIFT GATE #1?
YES
NO
2
SHIFT 16 BITS INTO ASSOCIATED REGISTER
3
SHIFT GATE #
NO
3
6
SEND MEMORY REQUEST TO MASTER PROGRAM CONTROL
ENABLE FCP TRANSMIT/ ERASE COMMANDS TO 0/I
7
HAS MASTER PROGRAM CONTROL ACKNOWLEDGED MEMORY REQUEST ?
YES
NO
7
STROBE X & Y ADDRESS TO MEMORY
TB ENTER COMMAND
YES
8
8
SET CHARACTER COUNTER TO BINARY -11 & Z BIT TO 1
STROBE A/N TO MEMORY
STROBE PARITY BIT TO MEMORY
ADVANCE COUNTER
STROBE TB-X BITS TO MEMOR
9
STROBE CONSOLE BITS TO MEMORY
ADVANCE COUNTER
STROBE X-DISPLAY COORDINATES TO MEMORY
ADVANCE COUNTER
STROBE Y-DISPLAY COORDINAT TO MEMOR

A

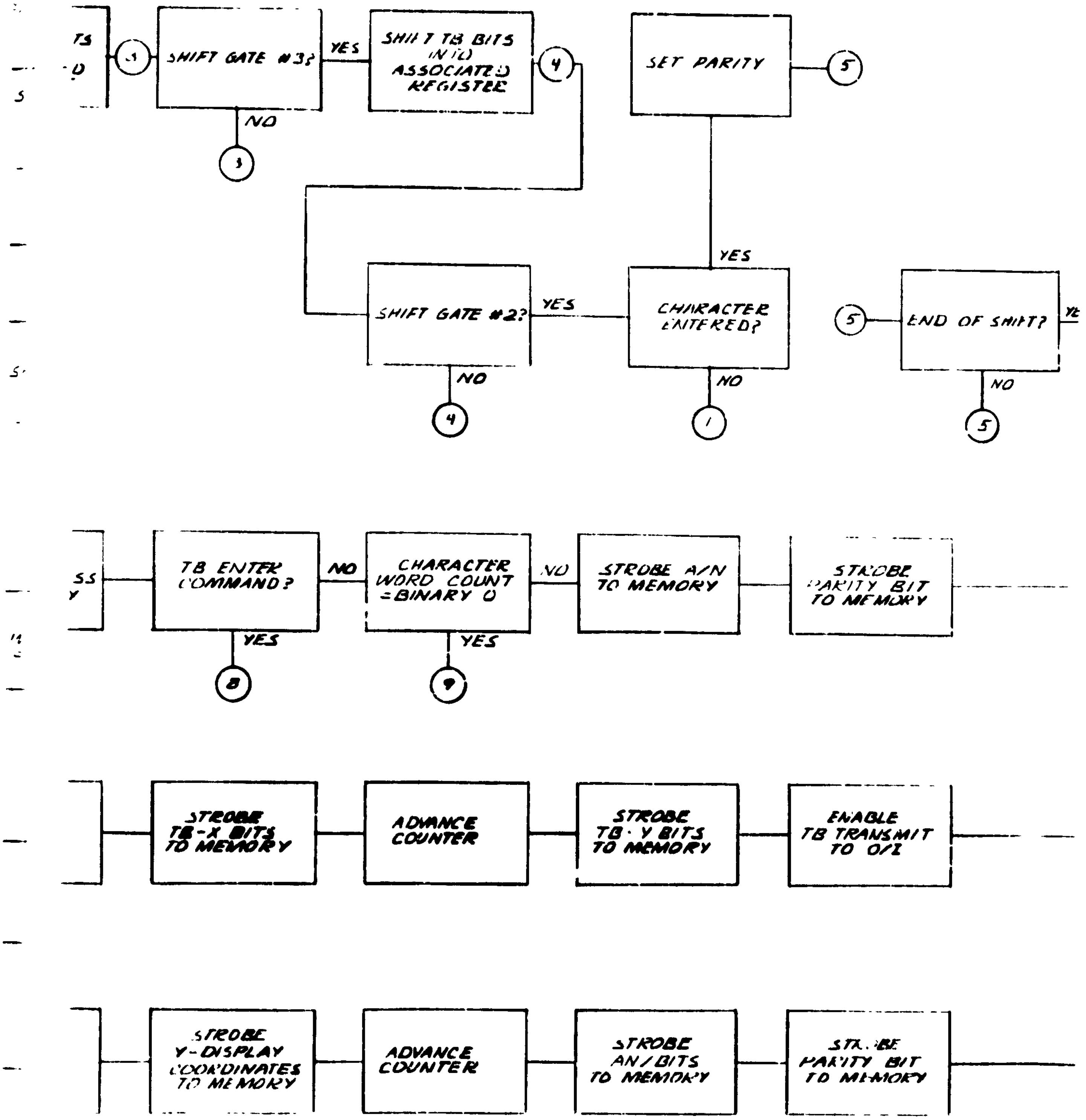

SHIFT GATE #3?
YES
NO
SHIFT TB BITS INTO ASSOCIATED REGISTER
SET PARITY
YES
SHIFT GATE #2?
YES
NO
CHARACTER ENTERED?
NO
END OF SHIFT?
NO
TB ENTER COMMAND?
NO
YES
CHARACTER WORD COUNT =BINARY 0
NO
YES
STROBE A/N TO MEMORY
STROBE PARITY BIT TO MEMORY
STROBE TB-X BITS TO MEMORY
ADVANCE COUNTER
STROBE TB-Y BITS TO MEMORY
ENABLE TB TRANSMIT TO O/I
STROBE Y-DISPLAY COORDINATES TO MEMORY
ADVANCE COUNTER
STROBE AN/BITS TO MEMORY
STROBE PARITY BIT TO MEMORY

Figure 3-2. Flow Diagram Common Logic (FCP)

during one vertical sync pulse time.

If the word is the first in a format, the counter bit is strobed into memory, counter advanced and X and Y display coordinates strobed into memory, the counter being advanced for each strobing. The counter is then set to 4 and the A/N character strobed in.

3. Trackball Flow Chart (See Figure 3-3)

The Trackball Flow Diagram is a presentation of the step by step logic involved in the trackball action of moving the slew dot to the target to find its X and Y display coordinates, then shifting the information into the FCP memory. Also the flow diagram presents the logic necessary for the generation of the slew dot on the RBDE-5 display.

The trackball action necessary to locate the target's X and Y display coordinates and shift this information into the FCP memory is contained in steps one through eight. If the Trackball Enter Button has not been pushed the logic says that the X and Y display coordinate information is not ready to be shifted into the FCP memory and that the operator is tracking the target in the X and Y coordinates. When the Trackball Enter Button has been pushed the target's X and Y display coordinates are correct and steps six through eight follow to shift the display coordinate information into the FCP memory.

Steps nine and ten describe the logic involved in generating the slew dot which is placed over the target on the RBDE-5 display to locate the target's X and Y coordinates. Steps nine and ten describe the X and Y compare action required in the trackball logic circuitry to put the slew dot at the correct position of the RBDE-5 display screen.

4. Slew Dot Positioning

During the initial POFA testing of the ANG at Atlanta, registration errors were noted between the track-ball-positioned symbol and the computer-positioned symbol. The magnitude and direction of these errors on the short range scales were sufficiently variable so as to require a thorough investigation into their causes. The investigation determined that the errors were produced in two areas, system and equipment.

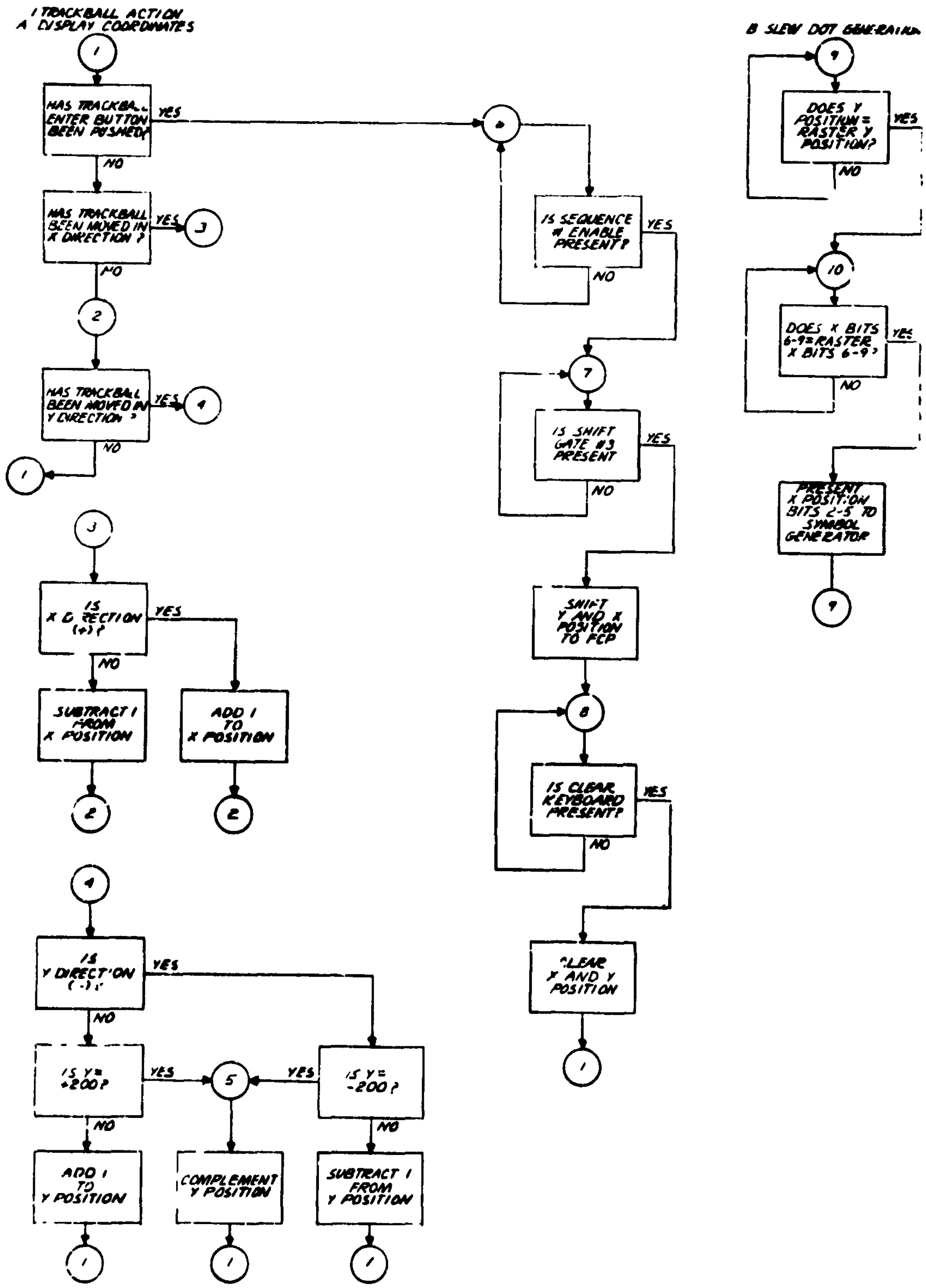


Figure 3-3. Trackball Flow Diagram

The characteristics of the ANG slew dot symbol positioning are described along with the causes of mis-registration between the TB positioned symbol and the computer positioned symbol in the original equipment in the ARTS and SPAN systems. This description includes sample equations used to determine the errors. Two modifications to the present equipment have been made to reduce the errors. The modifications and their results are described in detail with the results also listed in tabular summaries.

The ANG-Computer communications employs a 12 bit coordinate system with a resolution limited to 1/8 nautical mile. The symbol positioning differences produced by this resolution coordinate system exceeded the maximum allowable by the ANG specification on the shortest range scale and was responsible for up to 50% of the allowable error on all other terminal area range scales. Equipment deficiencies, including those determined by the established coordinate system, added to the above errors, inherent in the system. These additional errors were minimized by modification to existing logic but cannot be completely eliminated without major redesign of the ANG.

ARTS AND SPAN system registration differences were introduced by three factors; (1) system limitations, (2) equipment limitations, and (3) design decisions. The three factors are discussed along with the difference they cause and possible solutions. The basis for the study of the registration criteria is the last sentence of paragraph 3.3.6 of ER-D-406-050. This reads "Any point on the display face defined in the computer and slew dot coordinate systems shall register with a point at the same coordinates in the radar coordinate system or with ±0.100 inch on the 21 inch display face." This resolution, when converted to the ANG TV coordinate system of 800 vertical lines with 500 dots per line between grating bars becomes ±2.4 X video dots and ±3.8 Y video lines.

The greatest cause of registration error of the slew dot symbol position with respect to the computer target positioning was the inherent inability of the system to designate positions any closer than that defined by the value of the least significant bit of the coordinate data produced by the system.

Track data received from the computer will have coordinates conforming to that specified in paragraph 3.3.1.1 of -050. "The X and Y positions shall each be expressed in twelve bit binary

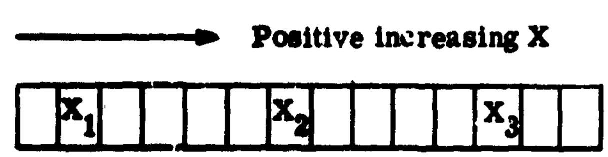
numbers, with the sign in the twelfth bit and the binary point three bits to the left of the least significant bit." Therefore, the computer coordinates define the spacing of tracks on the display surface to the value of the least significant bit of 1/8 nautical mile. That is, any coordinates transmitted to the computer or received from it cannot designate positions any closer than those listed in Table I.

TABLE I. SYSTEM DISPLAY RESOLUTION BASED UPON USE OF 12 BIT COORDINATE DATA

Range Scale	Display Resolution		
5 mile radius	1/8 mile = *0.262 in.	=6-1/4 =10	X dots Y lines
6.25 mile radius	1/8 mile = 0.21 in.	=5 =8	X dots Y lines
12.5 mile radius	1/8 mile = 0.105 in.	=2-1/2 =4	X dots Y lines
25 mile radius	1/8 mile = 0.052 in.	=1-1/4 =2	X dots Y lines
50 mile radius	1/8 mile = 0.026 in.	=5/8 =1	X dots Y lines

*On 21 inch diam. display.

For example: (one horizontal TV line)



$X_1, X_2, X_3, \ldots$ = X coordinates addressable by the computer on the 6.25 mile range scale.

$X_1, X_2, X_3, X_4, X_5 \ldots$ = X coordinates addressable by the computer on the 12.5 mile range scale.

All X positions are addressable by the Track Ball (TB); however, when TB coordinate data is transmitted to the computer, the ANG was designed so that all TB coordinates between X_1 and X_2 were transmitted as X_1, all coordinates between X_2 and X_3 as X_2, etc. The resolution of this data was to 1/8 nautical mile. The same considerations held for negative X coordinates as well as positive and negative Y coordinates.

The maximum difference between TB position and computer designated coordinates is as shown in Table II. The maximum differences are due to two factors; one, the use of 12 bit coordinate data limiting resolution to 1/8 nautical mile and two, the ANG coordinate processing, in discarding low order bits, not centering the resultant difference.

TABLE II. DISPLAY POSITION DIFFERENCE BETWEEN TB POSITIONED SYMBOL AND COMPUTER POSITIONED SYMBOL BASED UPON USE OF 12 BIT COORDINATE DATA

(Non-Centered Difference)

Range Scale	Maximum Display Difference	
	X dots	Y lines
5 miles	-6 (0.25 in.)	-8 (0.208 in.)
6.25 miles	-4 (0.166 in.)	-6 (0.156 in.)
12.5 miles	-2 (0.083 in.)	-2 (0.052 in.)
25 miles	-1 (0.042 in.)	0
50 miles	0	0
100 miles	0	0
200 miles	0	0

If the TB coordinate processing for the Terminal area range scales of 50, 40, 25, 20, 12.5, 10, 6.25 and 5 nautical miles is modified to permit TB coordinates which designate positions unaddressable by the computer to be transmitted corrected to the nearest computer addressable coordinate, then the maximum coordinate difference would be as shown in Table III. Positive errors indicate the error is away from the screen center axis, negative errors are towards the screen center axis.

TABLE III. DISPLAY POSITION DIFFERENCE
TERMINAL AREA ONLY
BETWEEN TB POSITIONED SYMBOL AND
COMPUTER POSITIONED SYMBOL BASED
UPON USE OF 12 BIT COORDINATE DATA

(Centered Difference)

Range Scale	Maximum Display Difference X dots	Maximum Display Difference Y lines
5 miles	+2 to -3 +0.083 ins -0.125 ins +0.04 mi. -0.06 mi.	±4 (+0.104 in.) (+0.05 mi.)
6.25 miles	±2 (±0.083 in.) (±0.05 mi.) (±0.05 mi.)	+4 to -2 (+0.104 -0.052 ins) (+.062 -031 mi.)
12.5 miles	±1 (±0.042 in.) (±0.05 mi.)	+2 (+0.052 in.) (+.062 mi.)
25 miles	+1 (+0.042 in.) (+.1 mi.)	+2 (+0.052 in.) (+.125 mi.)
50 miles	+1 (+0.042 in.) (+.2 mi.)	+2 (+0.052 in.) (+.25 mi.)

To reduce any differences below that shown in Table III would require the specification of coordinate data both to and from the computer to a greater resolution than 1/8 nautical mile. The use of coordinate data with greater resolution would require circuit changes to the ANG and changes to both the operational and POFA programs. However, without these changes, the ANG equipment cannot meet the specified registration requirements on the lowest range scales. The degree of ANG registration precision required on the other range scales is greater than that seemingly allowed by the ANG specification because of the presence of these system errors.

The second group of registration errors is introduced during the coordinate translation process within the ANG. One of these is presently due to the discarding of the low order coordinate data bits as the range scale is reduced from the maximum to the minimum and is caused by the maintenance of the value of the least significant bit at 1/8 nautical mile. The maximum error introduced by this process is less than the value of the transmitted least significant bit. The maximum position error is one displayed dot in X and 2 lines in Y. Another error introduced during the coordinate conversion process is due to the use of off-centering constants whose resolution is also to 1/8 nautical mile. The errors introduced by this do not exceed one displayed dot in X or 2 lines in Y.

To reduce the off-centering constants to less than one dot would require coordinate processing with a resolution greater than 1/8 nautical mile. This is not feasible without major circuit changes within the ANG.

The following empirical equations derived from the coordinate translation process will define the display difference between the TB symbol and the computer placed symbol as caused by the previously mentioned error sources. They are shown only for the X Track Ball coordinates (X_{TB}).

$$\frac{X_{TB}(Kml) - Eoc(2^{Sr})}{k} = N+R$$

Where Kml is the multiplier constant for the range scale type selected

(T.B coordinate processing)

Where Eoc is the error introduced by the off-centering constants and is equal to 1/8 nautical mile (max.)

Where Sr is the number of range shifts required in processing the coordinates: 6.25m Sr = 3;12. 5m, Sr = 2; 25m Sr = 1; 50m Sr = 0

Where k is the value of the least significant bit (1/8), multiplied by 2 for each range shift employed in the coordinate conversion process of K = 2 (St + Sr - 3) where St is the number of terminal shifts, if present.

Where N is an integer

Where R is a remainder. represents the error introduced by the 1/8 mile resolution maintained during range shifting, and is ignored.

Then,

$$X_{TB} - kNK_{m2} = M + r$$

Where km2 is the multiplier constant for the range scale type selected (Target coordinate processing)

Where M is an integer and represents the dots difference.

Where r is a remainder, represents a fractional dot error which cannot be generated, and is therefore ignored.

6.25 mi. range Terminal $\frac{.80078X_{TB}}{4} - \frac{1^*}{4} = N + R \quad X_{TB} - 5N$=dots differen

12.5 mi. range Terminal $\frac{.80078X_{TB}}{2} - \frac{1^*}{4} = N + R \quad X_{TB} - \frac{(5N)}{2}$ =dots differ

25 mi. range Terminal $.80078X_{TB} - \frac{1^*}{4} = N + R \quad X_{TB} - \frac{(5N)}{4}$ =dots differe

50 mi. range Terminal $\quad \frac{.80078X_{TB}}{.5} - \frac{1^*}{4} = N + R\,X_{TB} - \frac{(5N)}{8}$ = dots difference

25 mi. range Enroute $\quad .80078X_{TB} - 1^* = N + R\,X_{TB} - \frac{(5N)}{4}$ = dots difference

50 mi. range Enroute $\quad \frac{.80078X_{TB}}{5} - 1^* = N + R\,X_{TB} - \frac{(5N)}{8}$ = dots difference

100 mi. range Enroute $\quad \frac{.80078X_{TB} - 1^*}{.25} = N + R\,X_{TB} - \frac{(5N)}{16}$ = dots difference

200 mi. range Enroute $\quad \frac{.80078X_{TB} - 1^*}{.125} = N + R\,X_{TB} - \frac{(5N)}{32}$ = dots difference

*Where 1/4 in Terminal area calculations and 1 in Enroute area calculations represents the error introduced by the off-centering constants.

Similar equations were derived for Y_{TB}.

The third group of registration differences is caused by design decisions made to optimize the visual display presentation. There are two sources of error in this group. The first error is introduced by the use of the double dot wide, double line high TB symbol. This size has been chosen as the minimum recognizable symbol based upon human engineering factors. Its double dot size can at this position designate either of two TB coordinates. This can cause a maximum of one displayed dot error in X and a one line error in Y.

The second error is introduced by the compensation for delays in generating the TB symbol. The TB symbol is generated by the TB video generator. Since the circuits require a minimum time for TB symbol processing, a delay is introduced. To compensate for this delay a preset negative two count is added to the X_{TB} Coordinates. This preset count will introduce a maximum error of two displayed dots in X. This error will be toward the center axis of the screen in positive X and away from the center axis in negative X.

The total errors introduced in the system are listed in Table IV. These are the maximum differences in position that can be expected

TABLE IV. MAXIMUM DISPLAY DIFFERENCES
BETWEEN TB POSITIONED SYMBOL AND COMPUTER POSITIONED SYMBOL
ORIGINAL ANG I AND ANG II EQUIPMENTS

Range (miles)	Non-Centering Error	Coordinate Conversion Low Order Bits Discard	Display Off Centering	Double Size TB Symbol	Preset X TB Count	Maximum Display Difference
5 X	-6	-1	-1	-1	±2	+2 dots (+0.084 in. (+0.04 mi, -10 -0.42 -0.2)
Term Y	-8	-2	-2	-1	0	-13 lines(0.338 in. (0.163 mi.)
6.25 X	-4	-1	-1	-1	±2	+2 dots (0.084 in. (+0.05 mi. -9 -0.378) -0.225)
Term Y	-6	0	-2	-1	0	-9 lines (0.234 in.)(0.141 mi.)
12.5 X	-2	0	-1	-1	±2	+2 dots (+0.084 in. (+0.1 mi. -6 -0.252) -0.3)
Term Y	-2	0	-2	-1	0	-5 lines (0.130 in) (0.156 mi.)
25 X	-1	0	-1	-1	±2	+2 dots (0.084 in. (+0.2 mi. -5 -0.21) -0.5)
Term Y	-0	0	-2	-1	0	-3 lines (0.078 in)(0.187 mi.)
50 X	0	0	-1	-1	±2	+2 dots (+0.084 in. (+0.4 mi. -4 -0.168) -0.8)
Term Y	0	0	-2	-1	0	-3 lines (0.078 in.)(0.375 mi.)

TABLE IV. (Cont'd)

Range (miles)		Non-Centering Error	Coordinate Conversion Low Order Bits Discard	Display Off Centering	Double Size TB Symbol	Preset X TB Count	Maximum Display Difference
25	X	-1	-1	-1	-1	±2	+2 dots (+0.084 in. (+0.2 mi. -0.252) -0.6)
Enr	Y	0	0	-2	-1	0	-6 lines (0.078 in.)(0.187 mi.)
50	X	0	-1	-1	-1	±2	+2 dots (+0.084 in. (+0.4 mi. -5 lines(-0.21) -1.0)
Enr	Y	0	0	-2	-1	0	-3 lines(0.078 in.) (0.375 mi.)
100	X	0	0	-1	-1	±2	+2 dots (+0.084 in. (+0.8 mi.) -4 -0.168) -1.6)
Enr	Y	0	0	-2	-1	0	-3 lines (0.078 in.)(0.750 mi.)
200	X	0	0	-1	-1	±2	+2 dots (+0.084 in. (+1.6 mi. -4 -0.168) -3.2)
Enr	Y	0	0	-2	-1	0	-3 lines (0.078 in.)(1.5 mi.)

during a normal operation of the original design of ANG I at the FAA Atlanta, Ga. facility and the ANG II at the FAA Indianapolis, Indiana facility.

The errors remaining in the system after the introduction of the modifications are listed in Table V.

5. Core Memory Addressing Logic

During the preliminary system testing, it was found that some video bits were lost in the transfer of data from the core memory to the magnetic drum storage. Investigation revealed that during this core-to-drum transfer operation of the system cycle, which utilizes the read/read (1.7 μsec) mode of the core memory, the recovery time of the transformers used in the "y" core selection matrix was longer than the time between read/read pulses. This condition occurs only in the "Y" matrix and not in the "X" matrix due to the nature of the addressing sequence, which advances the "X" address sequentially while holding the "y" address fixed. It was therefore, necessary for eacy "y" driver to be pulsed 128 times in succession while due to the matrix each "X" was pulsed once for each eight "y" pulses.

The result of this high duty cycle was a reduction in the "y" half select current, which was sufficient to prevent core switching. A secondary effect was also observed; due to the saturation of the transformers, the primary current was double that expected, thus causing an overload condition in the drivers.

The two problems were solved by introducing logic (see Figure 3-4) which permitted the "y" drivers to be pulsed in a sequential fashion similar to the "X" drivers. The means by which this was accomplished was to add the three least significant bits of the "x" address to those of the "y" address, with the carry to the fourth bit ignored. The modification, while not disturbing the external system addressing, causes the internal stack addressing to proceed diagonally in groups of eight. The "y" transformers and drivers are therefore pulsed once out of eight read times, permitting transformer recovery and greatly reducing the overload conditions.

6. Console Identity Patching

During the design phase of ANG, a feature called Quick Look was built into the equipment. This feature provided a Controller with

TABLE V. MAXIMUM DISPLAY DIFFERENCES
BETWEEN POSITIONED SYMBOL AND COMPUTER POSITIONED SYMBOL
LIMITED MODIFICATION TO ORIGINAL ANG EQUIPMENTS TO CENTER THE DIFFERENCE

Range (miles)	Centered Error	Coordinate Conversion Low Order Bits Discard	Display Off Centering	Double Size TB Symbol	Preset X TB Count	Maximum Display Difference
5 X	+2 -3	0	-1	-1	±2	+4 dots (+0.168 in. (+0.08 mi. -7 -0.294) -0.14)
Term Y	±4	0	-2	-1	0	+4 lines (+0.104 in. (+0.05 mi. -7 -0.162) -0.087)
6.25 X	±2	0	-1	-1	±2	+4 dots (+0.168 in. (+0.1 mi. -6 -0.252) -0.15)
Term Y	+4 -2	0	-2	-1	0	+4 lines (+.104 in. (-0.063 mi. -5 -0.13) +0.078)
12.5 X	±1	0	-1	-1	±2	+3 dots +0.126 in. (+0.15 mi. -5 -0.21) -0.25)
Term Y	+2	0	-2	-1	0	+2 lines (+0.052 in. (+0.063 mi. -3 -0.078) -0.093)
25 X	-1	0	-1	-1	±2	+2 dots (+0.084 in. (+0.2 mi. -5 -0.21) -0.5)
Term Y	+2	0	-2	-1	0	+2 lines (+0.052 in. (+0.125 mi. -3 -0.078) -0.19)
50 X	-1	0	-1	-1	±2	+2 dots (+0.084 in. (+0.4 mi. -5 -0.21) -1.0)
Term Y	+2	0	-2	-1	0	+2 lines (+0.052 in. (+0.25 mi. -3 -0.078) -0.375)
25 X	-1	-1	-1	-1	±2	-6 dots (-0.252 in.) (-0.6 mi.)
Enr Y	0	0	-2	-1	0	-3 lines (-0.078 in) (-0.19 mi.)

TABLE V. (Cont'd)

Range (miles)		Centered Error	Coordinate Conversion Low Order Bits Discard	Display Off Centering	Double Size TB Symbol	Preset X TB Count	Maximum Display Difference
50	X	0	-1	-1	-1	±2	-5 dots (-0.21 in.) (-1.0 mi.)
Enr	Y	0	0	-2	-1	0	-3 lines (0.078 in.) (-0.325 mi)
100	X	0	0	-1	-1	±2	-4 dots (-0.168 in) (-1.6 mi.)
Enr	Y	0	0	-2	-1	0	-3 lines (-0.078 in) (-0.75 mi.)
200	X	0	0	-1	-1	+2	-4 dots (-0.168 in) (-3.2 mi.)
Enr	Y	0	0	-2	-1	0	-3 lines (-.078 in) (-1.5 mi.)

the capability of viewing all data available to any other sector receiving data from the same Radar Beacon source, providing the data fell within the geographic boundaries of the requesting viewer. The Controller would select the other channel to be QUICK LOOKED and depress a button. Upon the next display update cycle, the data would appear and remain until de-selected.

This design did not take into account the frequency of channel cross patching. During one sector organization period, adjacent sectors might be on adjacent channels; during another period, adjacent sectors might be several channels apart. It was desirable from a controllers viewpoint to maintain a fixed Quick Look selection capability independent of sector ANG channel location.

This change in Quick Look concept was performed by the use of a patching connector located on two printed circuit boards placed in slots 067 and 068 in the Code Translator chassis of the ANG. Taper pin jumper wires are used to cross patch pins on the patching connectors. This cross patch provides the means of maintaining sector identification independent of ANG channel switching.

7. The Sixty-four Second Minute

The velocity vector is defined by 6 bit "rate" coordinates. The value of the LSBs represent 1/128 n. mile per second. The vector fly time requirements are established as 1, 2, 4 and 8 minutes. The conversion of the 1/128 n. mile per second to miles per minute would require a major multiplication process resulting in an LSB of 60(1/128) or 0.46875 n. miles per minute. This multiplication process would add approximately 60 microseconds to each vector processing period.

To avoid the complex multiplication process with its increase in processing time, a decision was made early in the design phase to make use of a 64 second minute. This eliminated the multiplication process since the converted LSB value now become 1/2 n. mile per minute. The resultant vector display produced vector lines on the screen corresponding to one minute, four seconds when the 1 minute position was selected and up to eight minutes, thirty two seconds when the 8 minute position was selected.

Two techniques are available to generate a true 60 second minute vector. The first technique is to modify the ANG equipment to perform the calculations required to produce the LSB value of 0.46875 n. mile

per minute. The second technique is to modify the computer program to provide "rate" coordinates with an LSB value of 1/2 n. mile per minute. This would eliminate the requirement for any conversion process since the computer generated LSB value would be that number used directly by normal ANG vector generation processes.

C. Circuits

Under this heading are grouped five topics: noise analysis and reduction, magnetic drum refurbishment, magnetic drum read amplifier, synchronization of RBDE-5, and video mixer and line driver.

1. Noise Analysis and Reduction

In the process of testing each sub-unit, several circuit malfunctions were traced directly to noise pulses creeping into gated amplifier circuits. These noise pulses were present on each power supply buss as well as on the ground return busses, and were predominantly high frequency pulses. It was determined that the pulses were coincident in time with the leading edge of fast rise time pulses in the equipment, and were the result of voltage drop along the buss due to the impedance of the buss to the high current pulses. Tests performed on a typical buss to determine its impedance to the high current pulses revealed, as was expected from the high frequency nature of the noise, that the impedance is primarily the inductance of the buss.

Possible solutions to reduce the noise spikes were to lower the impedance of the busses or short circuit the noise at the source. Both methods are being utilized in all sub-units. The impedance of the ground returns was lowered by adding a newly designed buss between individual card row ground busses and by adding jumper wires to the chassis frame. This new buss, which is flat with relatively small cross-sectional area, was designed to have low inductance and thus lower the ground impedance. The noise voltage at the source is also reduced by the addition of by-pass capacitors from each voltage bus to ground at every card row in the rack. While these capacitors are not a perfect short to the noise, the noise was reduced to a level that eliminated triggering of the sensitive circuits.

In addition to measures taken to reduce the amplitude of the noise spikes, various circuits were desensitized to noise spikes by the application of the following: (1) replacing the pulse series resistor in triggering circuits with a zener diode, to increase the triggering threshold but without increasing the drive requirements: (2) shortening collector leads; (3) addition of isolation amplifiers at the output of flip-flops to

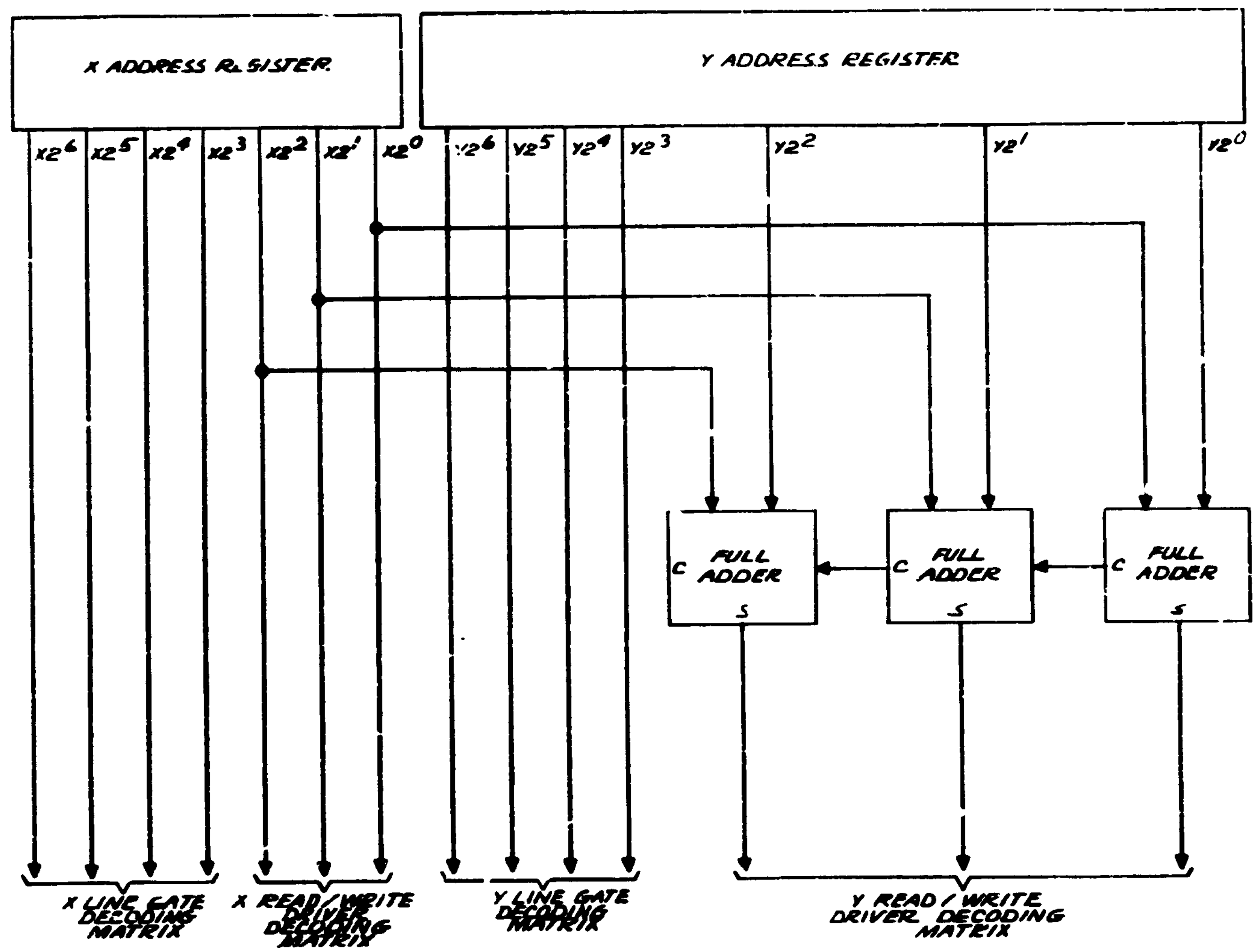


Figure 3-4. Core Memory Addressing Logic

prevent false triggering in their collector circuits; (4) insertion of series damping resistors; and (5) addition of clamping circuits.

2. Magnetic Drum Refurbishment

The original ANG design effort made use of state-of-the-art magnetic drums. The drum for the first ANG system provided a capacity for six ANG channels and made use of a magnetic oxide recording surface. The drum for the second system and the one provided under the spares program provided a capacity for ten ANG channels and made use of a magnetic cobalt recording surface, a more recent improvement in recording materials.

The cobalt surface provides a major increase in the drum reliability. It provides a thin, hard, dense surface capable of handling higher bit packing densities (recording frequencies) and produces a higher signal to noise ratio output. In the rare event of a head coming in contact with the drum surface, no damage is done to either head or drum surface. If the head surface contact is prolonged, the recording head would require replacement and no damage would be done to the drum surface.

A decision was made to make the first system drum interchangeable with the later two. This interchangeablility necessitated refurbishment of the drum in two areas; one, a resurfacing of the magnetic medium, replacing the oxide with cobalt and two, the addition of the recording play back heads required to increase the channel capacity from six to ten.

3. Magnetic Drum Read Amplifier

A new drum read amplifier has been developed and installed in ANG 1 and ANG 2 to avoid the display blanking associated with the amplifier originally used in ANG 1 and ANG 2. The problem of display blanking arises because of the fact that the read amplifier is normally disabled during the "write" or update time to prevent erroneous data output due to overloading the amplifier caused by the larget "write" currents. The new amplifier is not inhibited during update and, therefore, permits a fixed display without blinking.

The new read amplifier (Board Number 104058) has the following attributes:

> It amplifies low level drum play back signals as small as 20 millivolts.

Remains in the read mode during a record operation to avoid display blanking.

Has gain stability such that no variable resistors are required.

Figure 3-5 shows a schematic of board number 104058. Two identical read amplifiers are shown because the schematic is for an assembled board which contains two of the amplifiers.

The circuit is essentially a low level differential amplifier followed by an intermediate amplifier which drives the output multivibrator.

The input signal is applied to a differential amplifier stage formed by Q1 and Q2. The emitters of Q1 and Q2 are current fed through R6, R10 and R11 providing both ac and dc degeneration for good gain stability. R1 serves as a termination resistor for high frequency cable noise and thereby reduces the effects of such noise. R2 and R3 reduce the inductive time constant associated with the head winding and, therefore, aids the recovery of the amplifier during a record operation. The diodes, CR1 and CR2 limit the input signal to the bases of Q1 and Q2 during "write" time to prevent overloading the write amplifier.

Q3 serves primarily as a convenient means of coupling from the differential amplifier to the remaining single ended cascade amplifier Q4 with minimum sacrifice of common mode rejection. Q5 is a high gain linear amplifier when the bias gate at a pin 11/M is negative (normal read mode) but is transformed to a "normally off" switch when the bias gate is at zero volts (during record operation). This change in gain allows the amplifier to operate with the small signal playback from the drum as well as with the large signal present during "write" time. The time shift observed in the output pulse between a normal "read" signal and one derived from the "write" signal is approximately 200 nanoseconds. Q6 is a normally "ON" switch with a threshold bias on its base. The output of Q6 provides a trigger to a single shot multivibrator Q7 and Q8 which provides a fixed pulse width output independent of the amplitude and width of the input signal. The output of the amplifier appears at the collector of Q9 which is a low impedance line driver.

4. RBDE-5 Synchronization

a. 614 KC Filter

The RBDE-5 display accepts from the ANG a 3.6855 Mc master clock signal which is used to produce the horizontal and vertical

synchronization pulses. The 3.6855 Mc signal is derived in the ANG from the 614 Kc track on the Magnetic Drum (See Figure 3-6.)

When making system tests it was observed that the horizontal sweep lines on the RBDE-5 display started at random horizontal positions near the edge of the display. These irregularities were traced to pulse-to-pulse jitter of the 614 Kc drum clock track. The jitter is developed in the amplification process of the drum clock track signal because of the slow rise time (614 Kc) and amplitude variations of read head output. After investigation it was concluded that the jitter represented the "state of the art" in drum recording and readout of sine waves, and that a major effort would be required to attempt to eliminate jitter at the source.

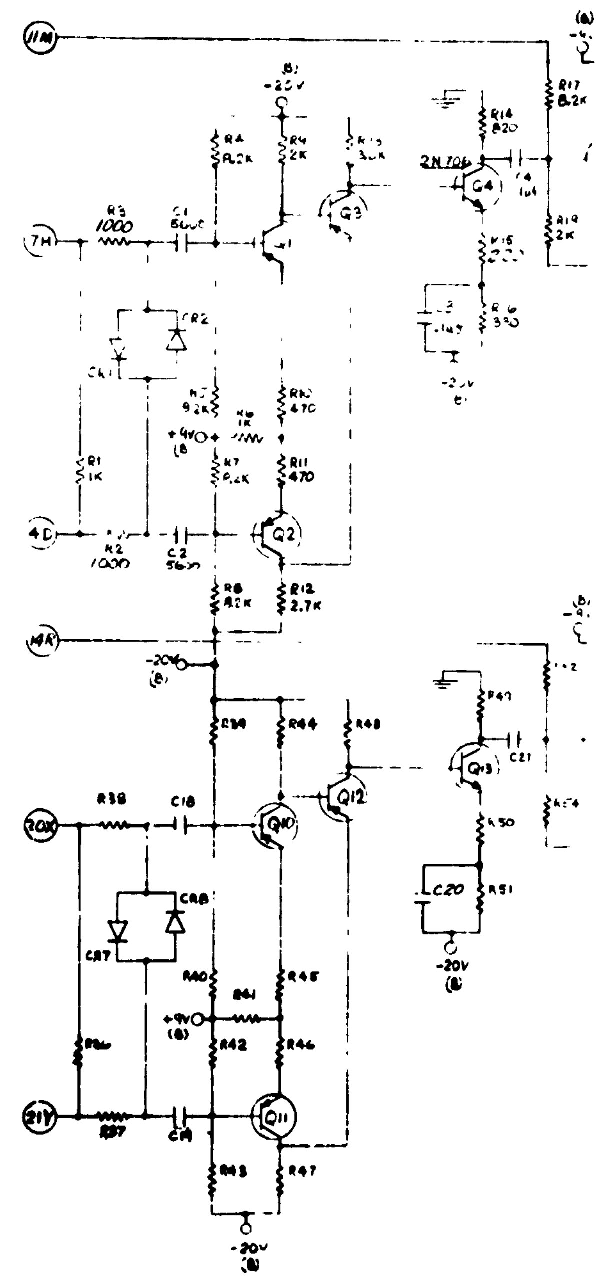
The approach taken was to reduce the jitter to an acceptable level by filtering the drum clock track output. The spectral distribution of the drum clock track output was observed with a low frequency spectrum analyzer. This revealed that a 614 Kc signal existed with sidebands spaced at 6 Kc intervals from 20 Kc up to 10 Mc. This indicated that the pulse to pulse jitter was a form of modulation where modulation rate is 6 Kc. From this it was concluded that if sidebands were eliminated a sine wave at 614 Kc would be obtained with no modulation or jitter. The drum clock output was passed through a bandpass filter (see Figure 3-7) with sufficient bandwidth to accept long term variations in the 614 Kc due to power line frequency variations (±5%) but still attenuated most of the sidebands.

As expected, the jitter was reduced to an acceptable level. The filter presently being used has a ±5% bandwidth and the jitter has been reduced to a level comparable to that of a crystal oscillator.

b. **3.6855 MC Filter and Amplifier**

The RBDE-5 requires 3.6855 Mc input for its master synchronizer. The 3.6855 Mc is derived from the drum clock track which is at a 614 Kc rate.

The difficulty encountered in multiplying the 614 Kc to the desired 3.6855 Mc is that the frequency multiplier must be capable of tracking input frequency variations up to ±5%. The technique used to develop the 3.6855 Mc from 614 Kc is to distort the 614 Kc waveform in such a fashion so as to enrich its harmonic content, particularly the 6th. This is done by passing the 614 Kc sine wave through a saturated amplifier which produces an asymmetrical waveform. This waveform is then applied to a 3.6855 Mc bandpass filter; this filter selects only



4. ADD C3, C20 CHANGED R2, R3, R15, R37, R38, R50, R17, R52
3. R56, R61 - was 6.8K
2. Q4, Q16 - was 2N1289
REV A - 12/8/64 - 1. DELETE C3, C20 - (.1μf).

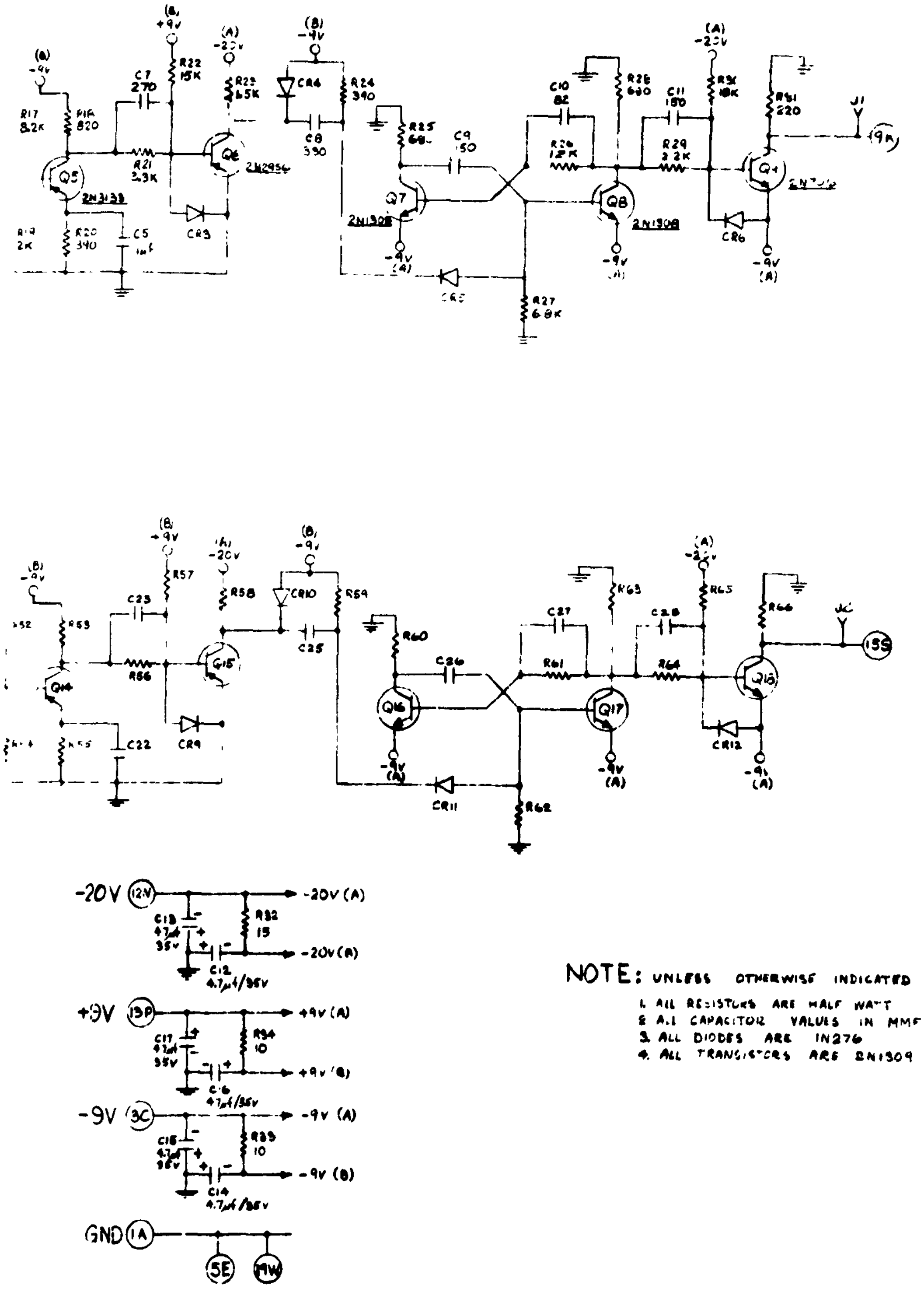
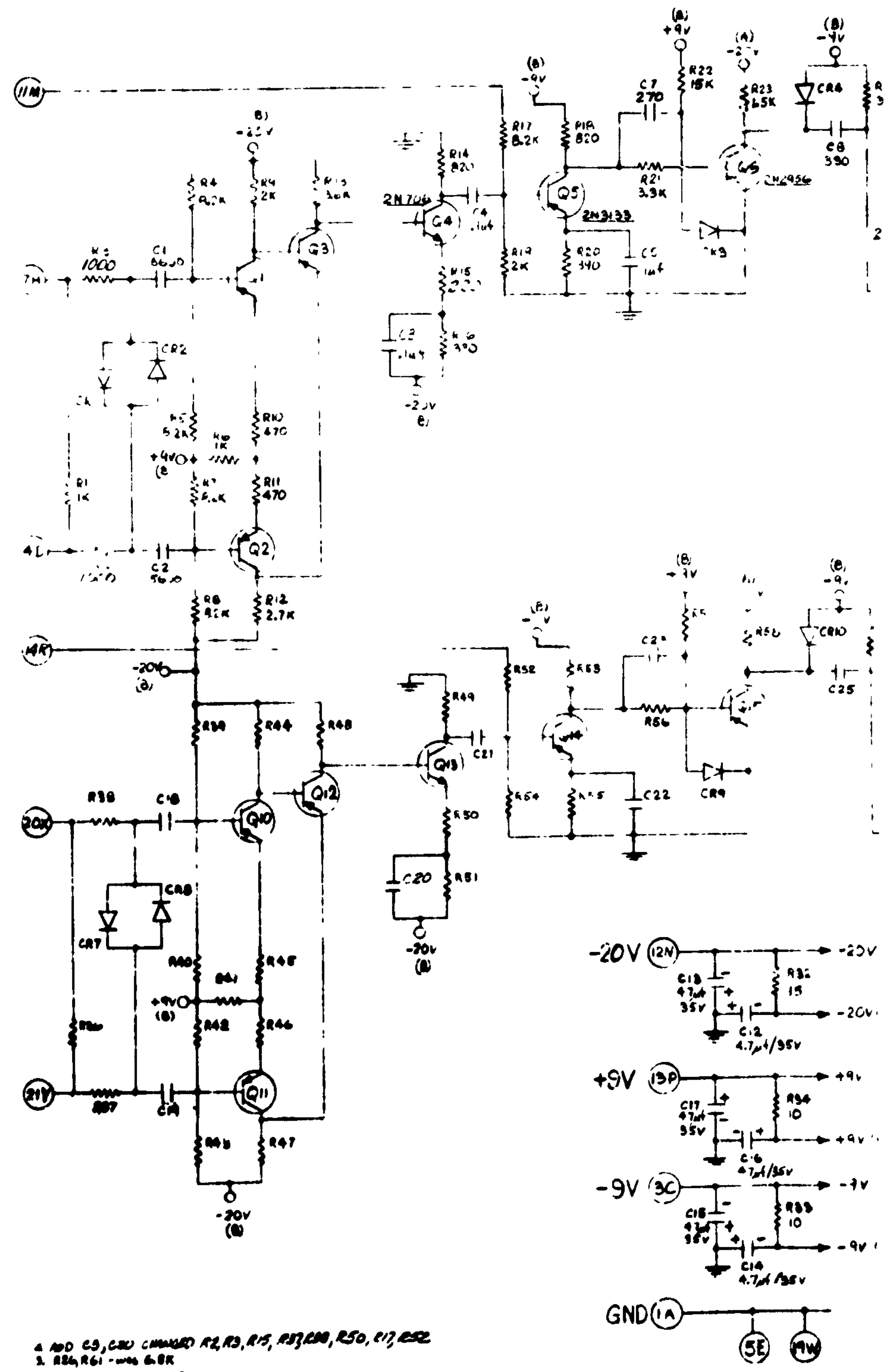
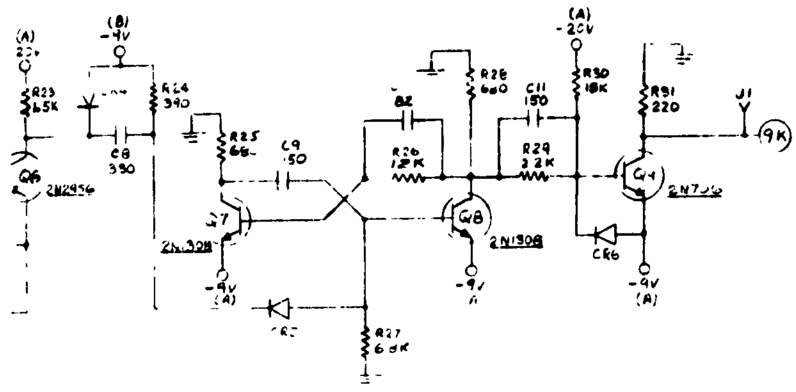


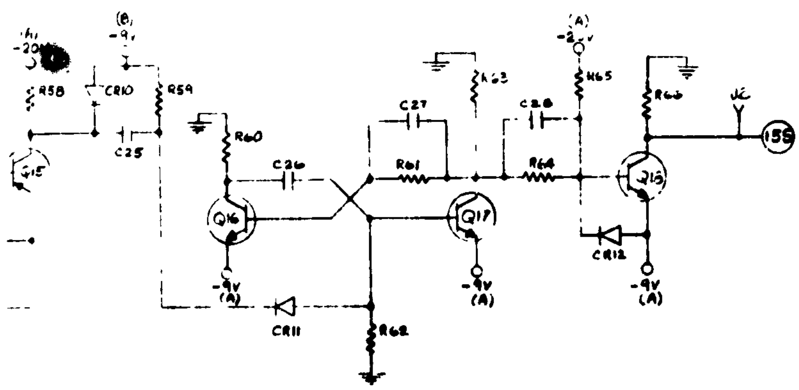
Figure 3-5. Read Amplifier Circuit

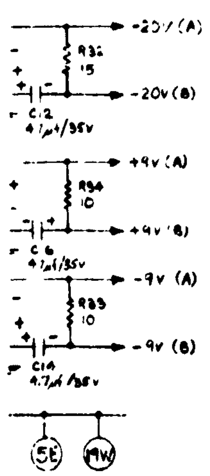


4 ADD C3, C20 CHANGED R2, R3, R15, R37, R38, R50, R17, R52
3. R56, R61 - was 6.8K
2. Q4, Q13 - was 2N1209
REV A - 12/16/64 1 DELETE C3, C20 - (.1µf).

A







NOTE: UNLESS OTHERWISE INDICATED

1. ALL RESISTORS ARE HALF WATT
2. ALL CAPACITOR VALUES IN MMF
3. ALL DIODES ARE IN276
4. ALL TRANSISTORS ARE 2N1309

Figure 3-5. Read Amplifier Circuit

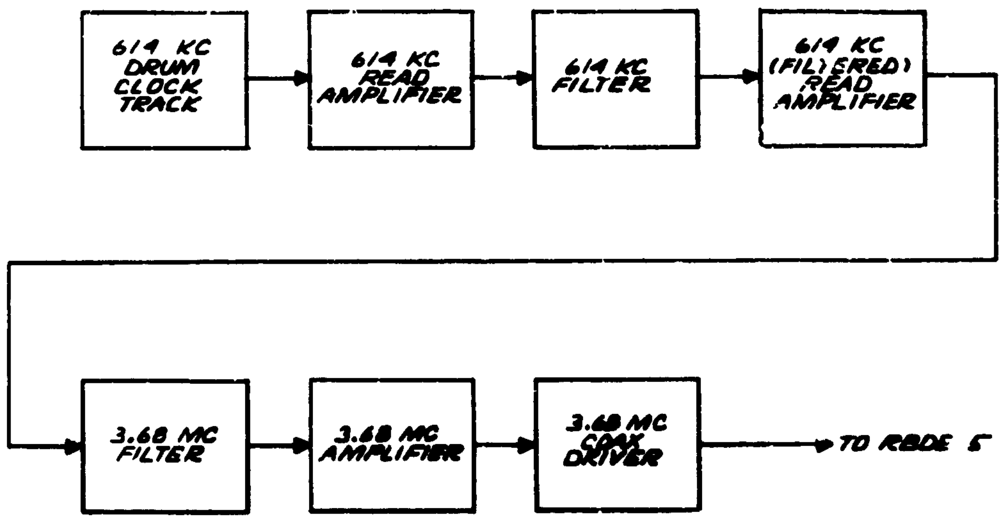


Figure 3-6. RBDE-5 Synchronization Block Diagram

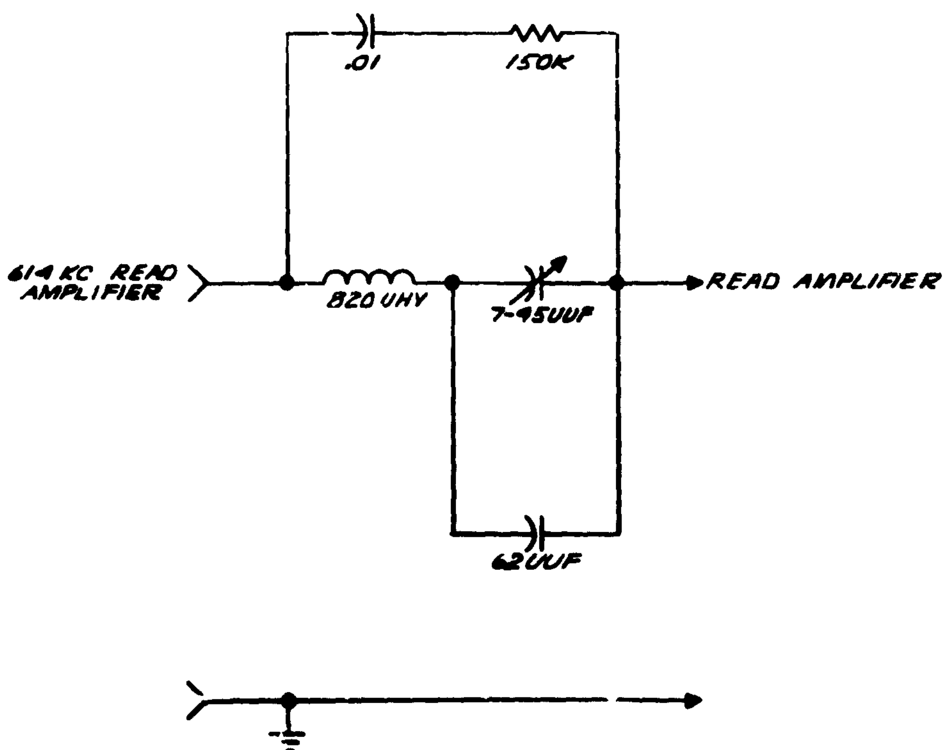


Figure 3-7. 614 Kc Filter

the desired harmonic, but has sufficient bandwidth to accept the ±5% frequency variations.

The filter is a 3 pole network with Tchebycheff response characteristics. To overcome the filter insertion loss, low amplitude of the 6th harmonic, and to satisfy the high output impedance requirements, the filter is followed by a Darlington emitter follower and an amplifier. See Figure 3-8.

This filter-amplifier combination is presently being used and operates over the required frequency range.

5. Video Mixer and Line Driver

The function of the Video Mixer and Line Driver is to accept data pulses from the Video Generator and from the Track Ball Symbol Generator, combine the data and present the resultant video signal to the RBDE-5 for display. See Figure 3-9.

Eighteen megacycle, two volt video data pulses are presented to the base of Q1 through R2 from the Video Generator. Track Ball video pulses approximately 2 volts in amplitude, are presented to the base of Q2 through R5 from the Track Ball Symbol Generator.

Potentiometer R2 and R5 adjust the amplitude of the two inputs to equal each other, so that the display intensity of the track ball symbol will be the same as the intensity of the other video.

Transistors Q1 and Q2 form a binary OR circuit. The output of the OR circuit, from the emitters of Q1 and Q2, is inverted and amplified by Q3, to a 3.6 volt amplitude. Emitter follower Q4 amplifies the current and drives grounded base stage Q5. CR1 biases Q5 and R13 controls the operating point of Q5. The output of Q5 drives inverter Q6. The output amplitude of Q6 is controlled by the Remote Gain Control on the Function Control Panel. The Remote Gain Control biases grounded base stage Q8, which determines the dc voltage at the emitter of Q8. The voltage at the collector of Q6 is clamped through CR3 so that it can never go more positive than the voltage at the emitter of Q8. Thus the Remote Gain Control adjusts the "clamp voltage" of the signal at Q6. Emitter follower Q7 drives line driver Q9. CR4 and CR5 bias Q9, and R27 adjusts the operating point of Q9 through 75 ohm coaxial cable. Transistors Q3, Q5, and Q9 are provided with radial fin heat sinks to increase their power dissipation capabilities.

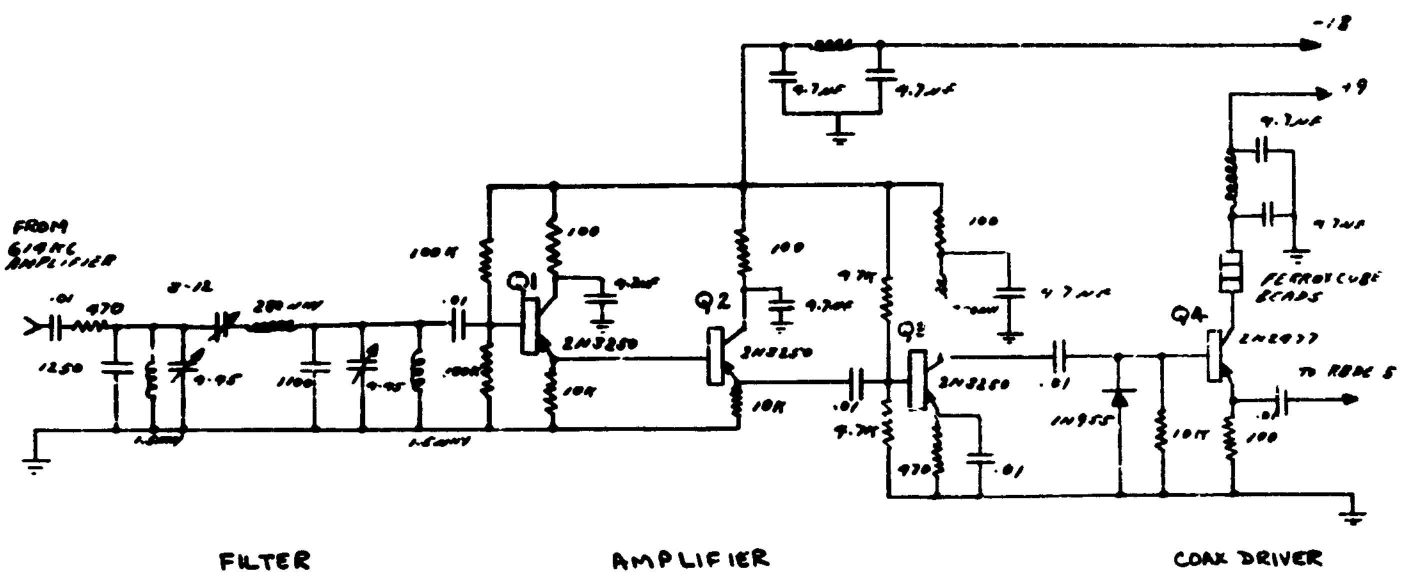
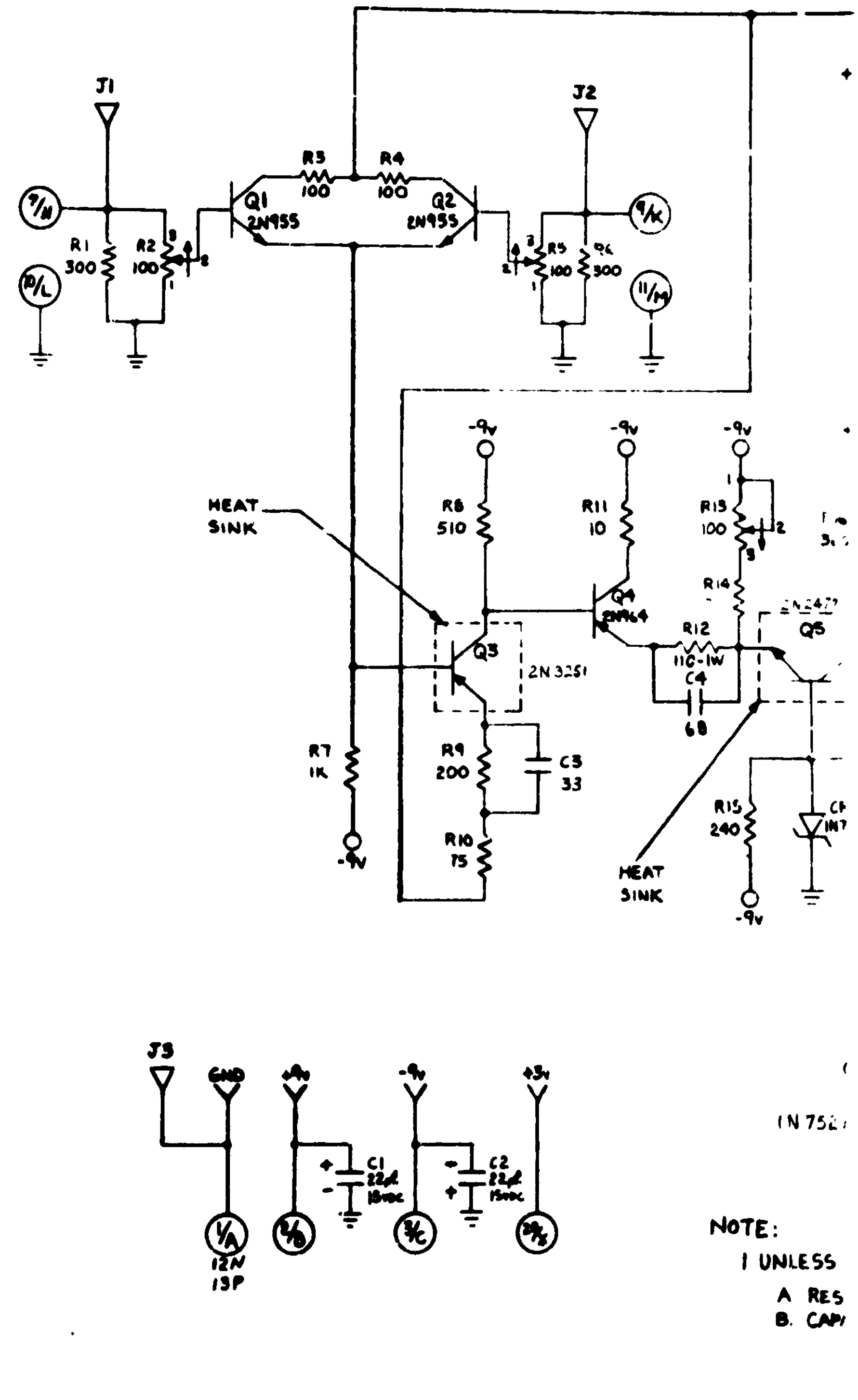


Figure 3-8. 3.68 Mc Amplifier and Filter


J1
J2
R3
100
R4
100
Q1
2N955
Q2
2N955
R1
300
R2
100
R5
100
R6
300
HEAT
SINK
-9v
R8
510
R11
10
R13
100
Q4
2N964
R14
R12
110-1W
C4
68
Q5
Q3
2N3251
R7
1K
R9
200
C3
33
R10
75
R15
240
HEAT
SINK
J3
GND
-9v
+3v
C1
C2
12N
13P
IN 752
NOTE:
1 UNLESS
A RES
B. CAP

A

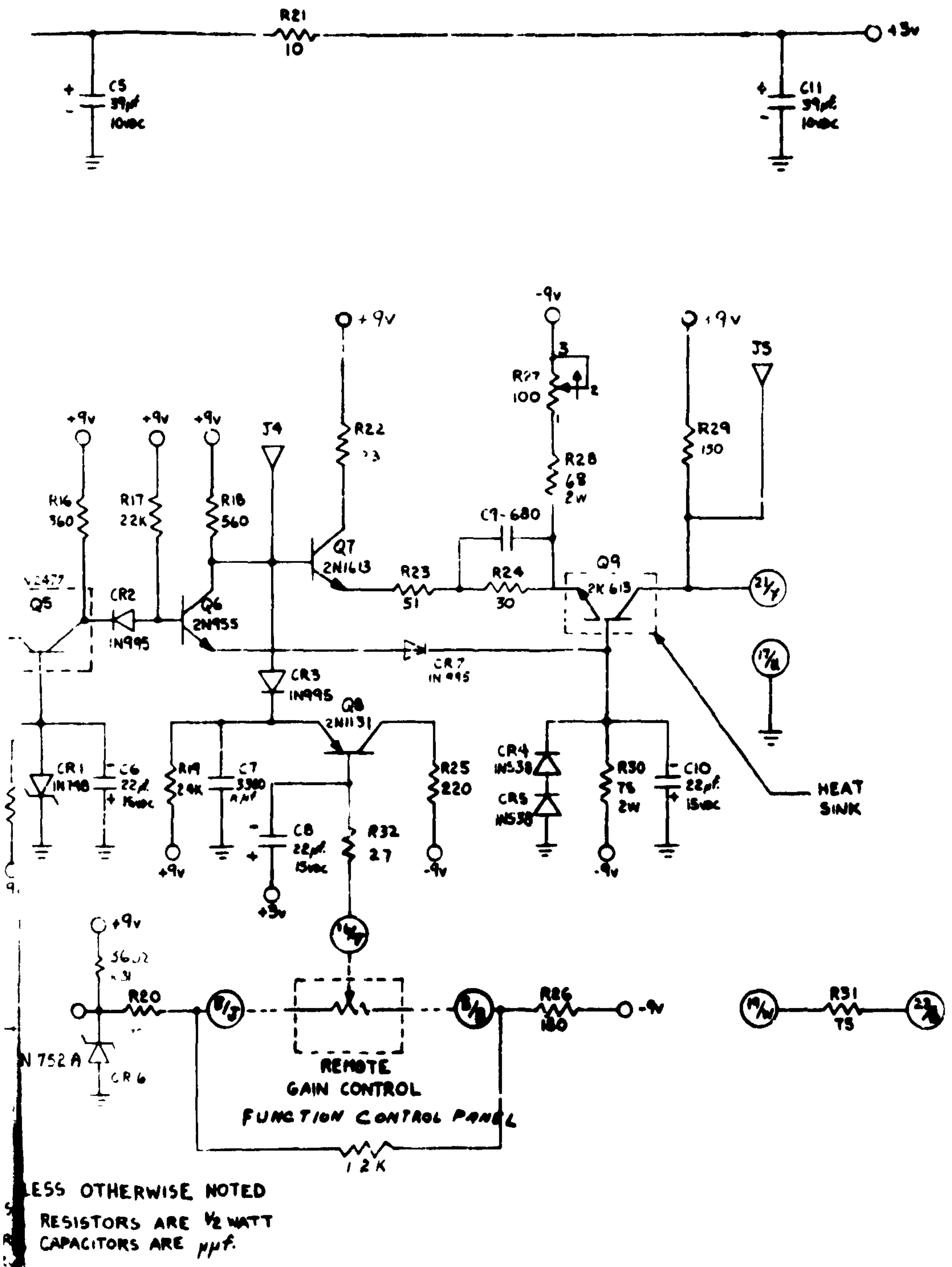
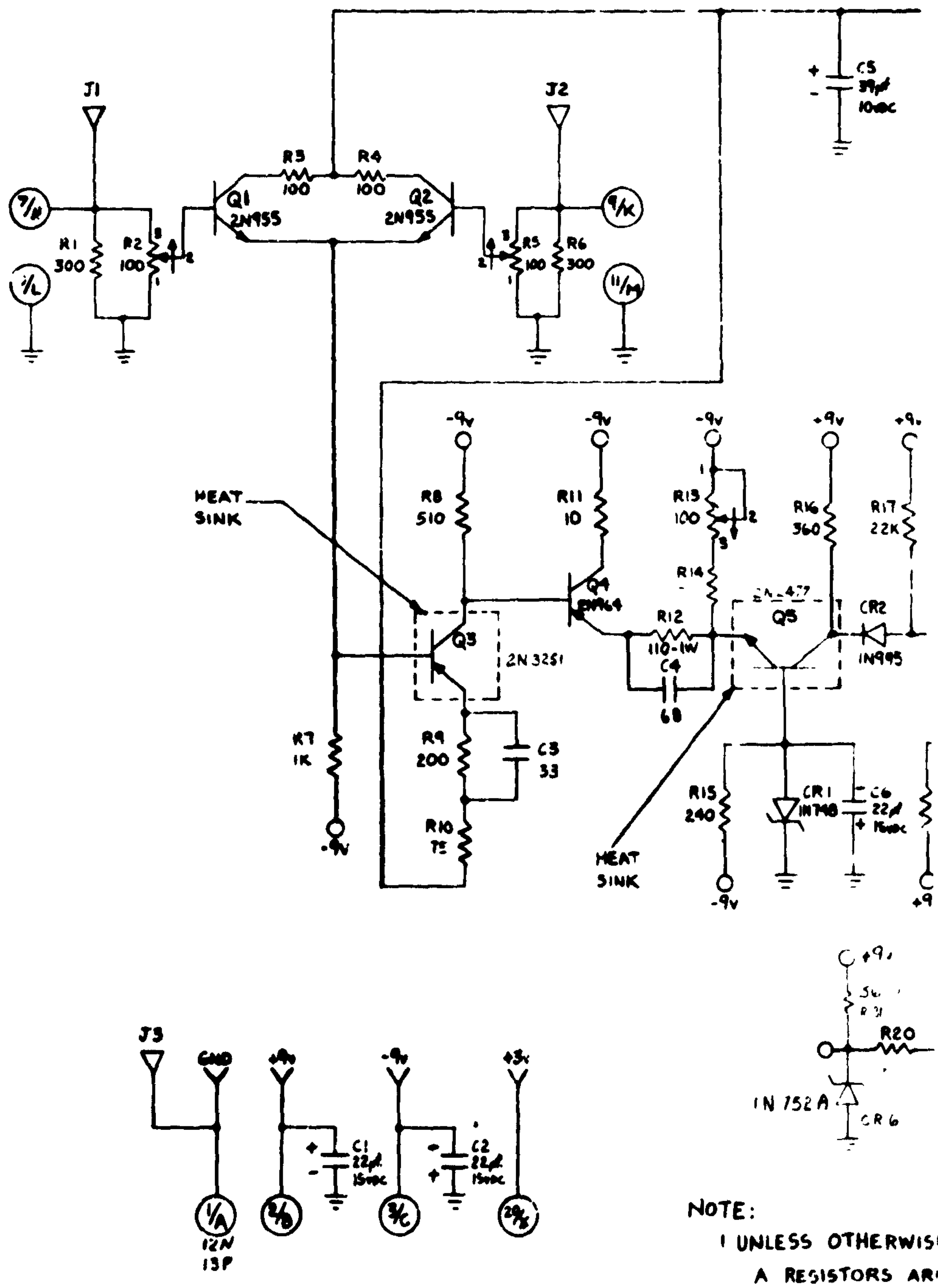


Figure 3-9. Video Mixer and Line Driver

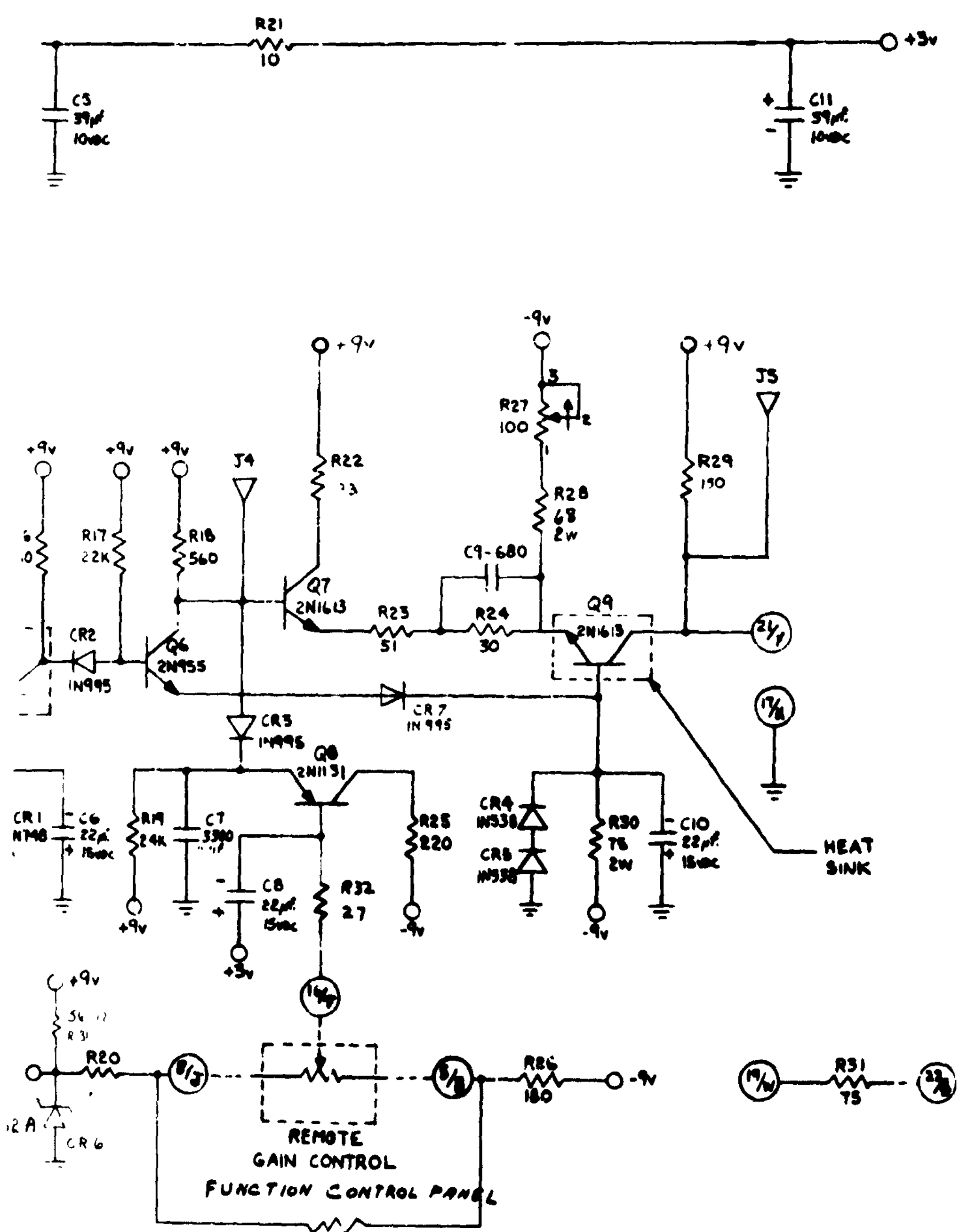


NOTE:

1 UNLESS OTHERWIS

A RESISTORS AR

B CAPACITORS ARE



S OTHERWISE NOTED
ESISTORS ARE ½ WATT
APACITORS ARE μμf.

13

Figure 3-9. Video Mixer and Line Driver

D. System Interfaces

1. Interconnections Between the ANG and RBDE-5

The ANG receives off-centering and range information from the display by sensing the condition(s) of a set of relays in the associated scan converter cabinet of the RBDE-5.

The off-center information is obtained from the shaft encoders B5005 and B5006 in the scan converter cabinet. This information is picked up at the output terminals of the off-center/no off-center relays K5004 and K5005. To obtain the off-center position information a wire is required from each of the following connectors: TB5023 connections 11, 12, 13, 14, 15 and 16; TB5024 connections 11, 12, 13, 14 and 15. (See figure 3-10.)

The off-center position is transferred as two five-bit digital words (one word defines East-West position. The other word defines North-South position).

The range scale information is transferred as a shift register word. Six separate wires are used to convey range information for ANG-1 (ARTS) five separate lines are used for ANG-2 (SPAN), but only one of the lines will be energized at a time. The energized line will correspond to one of the display range scales.

Range information is obtained from the unused contacts of relays (in the RBDE-5 Scan Converter Cabinet) K5101, K5102, K5103, K5104, K5105 in the SPAN system. For the ARTS system one additional relay is used, K5107. See figure 3-11 Range Scale wiring details for ARTS and SPAN. One wire is required for each relay to transfer the range information and one wire per scan converter is required to enable the readout of range data. The information lines are connected to pins number 9 of each relay, the enable line connects to all pins #10.

The range scale and off-center data from each scan converter are inputs to a multiplexer in the ANG equipment. The ANG can select the set of range scale and off-center data from the appropriate scan converter via the multiplexer.

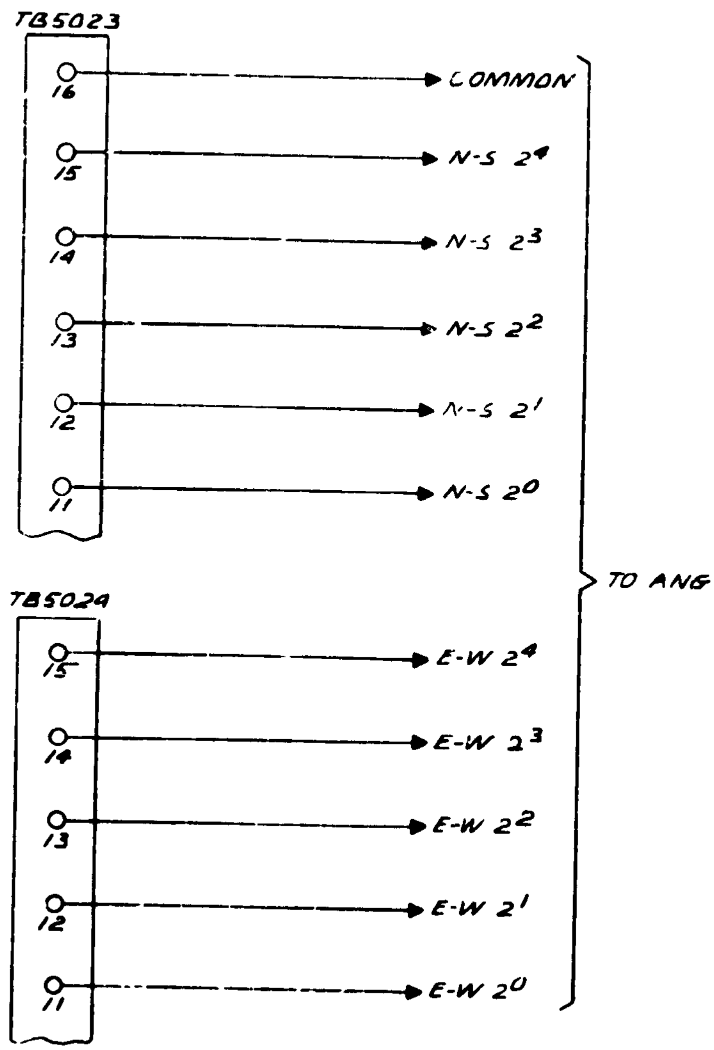


Figure 3-10. Off-Center Wiring

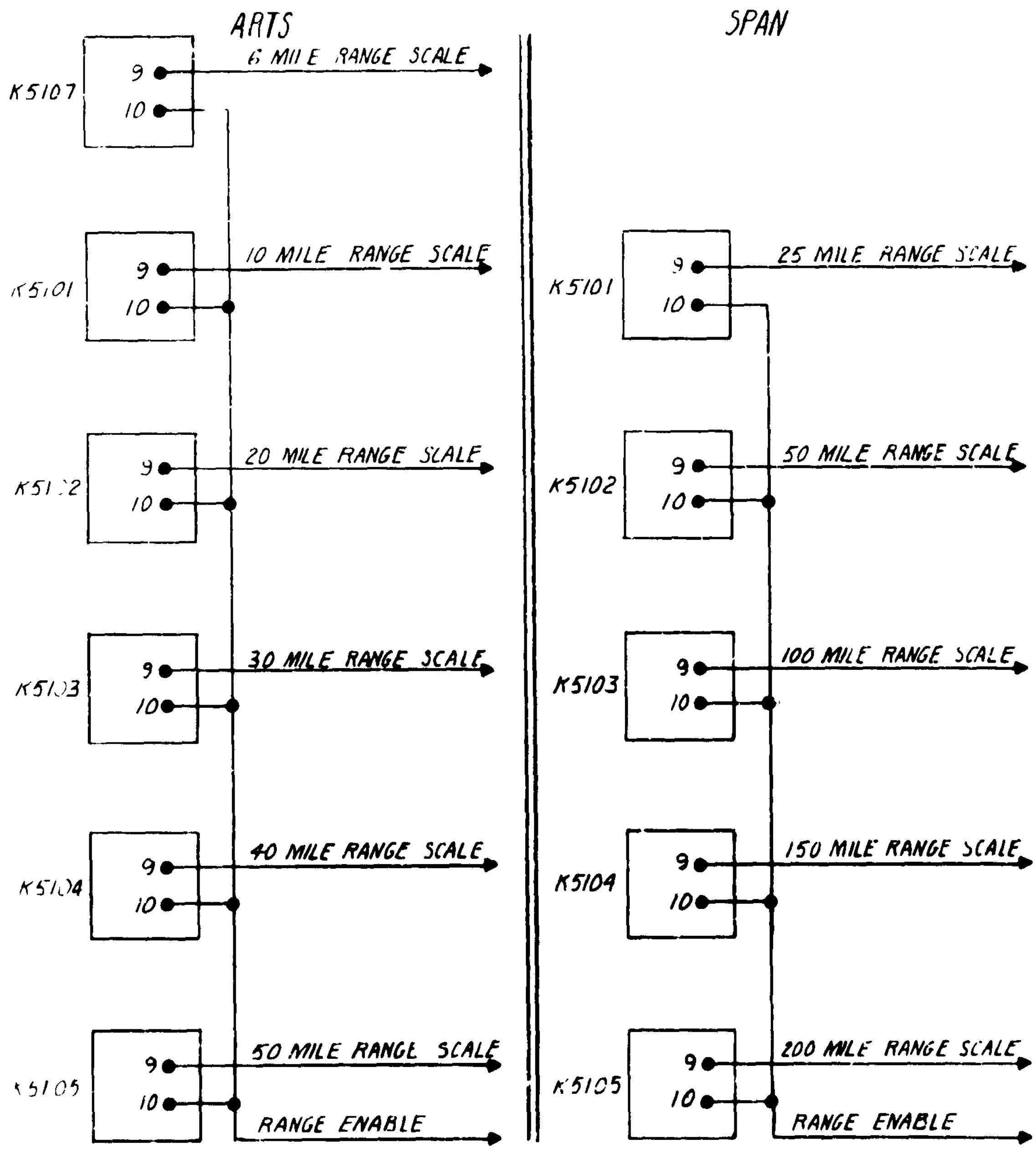


Figure 3-11. Range Scale Wiring for ANG-1 and ANG-2

2. Multi Radar/Beacon Installations

The Alpha-Numeric Generator can operate in a Multi-Radar Beacon environment with up to four Radar Beacon Systems. The ANG-2 in the SPAN system accepts inputs from three separate Radar Beacon Systems. Each computer generated track format contains Radar Beacon identification bits in addition to the console identification bits. The Radar Beacon bits indicate which o the three Beacon Systems is supplying the target information. Each bit position corresponds to a specific Radar Beacon System

Each Scan Converter is supplied by a discrete Beacon Syst. The Scan Converters specify the Beacon identification to the AN by the set bit position on its Beacon Indicator lines to the ANG.

During display processing, if a track format is not address to the display console being updated, the Beacon Identification bits are examined to determine if the track format symbol is to be printed. If the respective Beacon System bit for the display is set, the track format symbol is printed. This indicates that the track is being followed by the same Beacon System that is supplying the display. If the respective Beacon System bit is not set, the track format symbol will not be printed. This indicates that the track is not being followed by the same Beacon System t is supplying the display. This technique is used to avoid display the same track at two different locations if the two Beacon Systen do not identically track.

The computer could, in addition, set all track format Radar Beacon identification bits, thereby putting track format symbols on all displays not addressed to a particular track format. Also, the computer may not set any of the identification bits, thereby inhibiting display of the track symbol on any but the addressed console.

3. **Range Switches (ANG)**

A switch panel is installed on the front of rack 100K to facil. the transfer of range information to the Alpha-Numeric Generator (ANG) from the individual displays (RBDE-5 Scan Converters).

The Scan Converter is capable of operating with the range se ting shown in Table VI below.

TABLE VI
RBDE-5 RANGE SCALES IN MILES

ARTS	SPAN
50	200
40	150
30	100
20	50
10	25
6	

The Alpha Numeric generator is capable of processing information corresponding to the two types of range information shown in the table below.

TABLE VII
ANG RANGE SETTING

Type I	Type II
200	160
100	80
50	40
25	20
12-1/2	10
6-1/4	5

Both sets of range settings are categorized as shown in the table below:

TABLE VIII
RANGE SETTINGS

ARTS (ANG-1)			SPAN (ANG-2)		
RBDE-5	Terminal		RBDE-5	Enroute	
Range Settings	Type I	Type II	Range Settings	Type I	Type
50	50	--	200	200	--
40	--	40	150	--	160
30	25	--	100	100	80
20	--	20	50	50	40
10	12-1/2	10	25	25	20
6	6-1/4	5	--	--	--

The range data is transferred from the RBDE-5 by energizing one of the information lines from each display (RBDE-5). Rows of switches are provided in one ANG chassis for associating the range settings with their proper values.

The range switch panel on the 100K series chassis of the Common Equipment Cabinet contains six columns of switches. A typical row of switches for a single display is shown below:

Enroute	100/25	50/12-1/2	25/6-1/4	Up	Left
Terminal	80/20	40/10	20/5	Down	Right

The Enroute/Terminal switch informs the ANG which of the two modes the range setting corresponds to. Thus if Enroute has been selected, the first range switch selects 100 or 80 miles; the second 50 or 40, and the third 25 or 20. Similarly, if Terminal has been selected, the first range switch selects 25 or 20 miles; the second 12-1/2 or 10 and the third 6-1/4 or 5. The maximum range scales are selected directly by the scan converter range scale selector switch. In the Enroute mode, the scan converter range switch directly selects the 200 and 160 mile ranges. In the Terminal mode, the scan converter range switch directly selects the 50 and 40 mile ranges.

A modification in the above range scale selection capability was made to the ANG-1 for the ARTS program. This modification deleted the first range switch. Thus, the scan converter range selector switches associated with ANG-1 could directly select 200, 160, 100, and 80 mile ranges in the Enroute mode or 50, 40, 25, and 20 mile ranges in the Terminal mode.

Note that the up positions of the above pictured range switches correspond to a Type I range setting and that the down positions correspond to a Type II range setting. The remaining two switches are not associated with the transfer of range information from the displays to the ANG.

4. ARTS-ANG Interconnections

The interconnection of ANG-1 with other parts of the ARTS Display Subsystem is shown in Figure 3-12. This sketch represents the configuration agreed upon at the FAA/Hazeltine meeting held at Atlanta. The type and quantities of interconnection cables and connectors which have been selected are as shown in Figure 3-13 and Table IX.

a. Power and Ground Bus

Approximately 4 Kw of 208 volt, 60 cycle, 3 phase, power is supplied to ANG-1 from a 3 phase circuit breaker in an FAA distribution box. Conduit between ANG-1 and the distribution box is supplied and installed by FAA and contractor supplied cable or wire is pulled into the conduit by FAA and connected to the distribution box circuit breaker.

In order to ensure a common ground reference between ANG-1 and associated subsystems, a ground bus (#4 Welding Cable) is provided and installed between ANG-1 and the system ground.

b. A/N TV Video

Six channels of A/N TV Video are supplied from the ANG-1 Drum Cabinet (1030k) to the RBDE-5 CRA Unit No. 1 via 6 RG-59/U coaxial cables (W10121, W10123, W10125, W10127, W10131). BNC connectors are employed at both ends.

Within CRA Unit No. 1, these six video channels are connected (FAA modification) via miniature coaxial cables (RG-187) to six spare Dag Connectors provided on the back of "Video Mixers Input 3" patch panel. From the patch panel ANG-1 TV video is distributed to appropriate video mixers where it is mixed with scan converter video and sent to the display consoles for viewing.

c. Functional Control

Communication between ANG-1 and the six display console positions is accomplished on a channelized basis. At each of the six positions, Trackball information, Category/Function selection, Display Control selection, Format Inhibit/Select selection and the output from the A/N keyboard are individually connected into a common Functional Control Panel junction box.

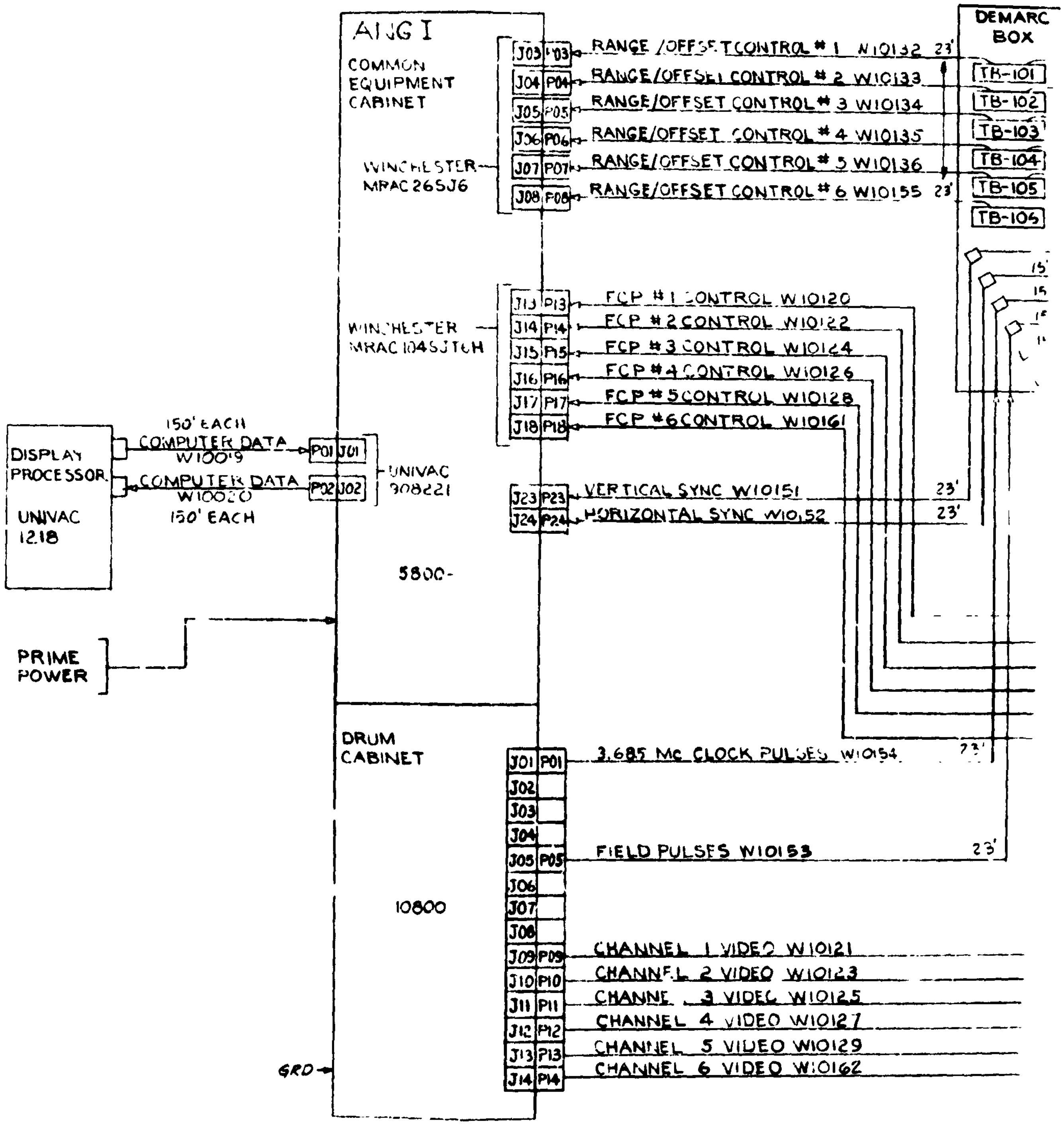
At each display console, a single, multi-conductor cable (contractor furnished) is used to connect the FCP junction box to ANG-1. Thus, six cables (W10120, W10122, W10124, W10126, W10128, W10130) are used in Atlanta installation.

d. Subsystem Interface

In order to provide a convenient and clearly defined subsystem interface, a "Demarcation Box" or junction box (GFE) is employed between ANG-1 and the RBDE-5 subsystem. All connections between ANG-1 and the balance of the RBDE-5 display subsystem other than the six A/N TV video lines to RBDE-5 CRA Unit 1, are made at this box. The "Demarc" box will enable the contractor to confine his activities between ANG-1 and the interface thus avoiding inadvertent disturbances to RBDE-5 cabling, critical in an operational environment.

e. Synchronization

The RBDE-5 Display Subsystem is synchronized by clock pulses at a 3.685 Mc rate. These clock pulses, whose basic source in the ARTS System is ANG-1 drum memory,



AN/GI
COMMON EQUIPMENT CABINET
WINCHESTER MRAC 26SJ6
RANGE/OFFSET CONTROL # 1 W10132 23'
RANGE/OFFSET CONTROL # 2 W10133
RANGE/OFFSET CONTROL # 3 W10134
RANGE/OFFSET CONTROL # 4 W10135
RANGE/OFFSET CONTROL # 5 W10136
RANGE/OFFSET CONTROL # 6 W10155 23'
DEMARC BOX
TB-101
TB-102
TB-103
TB-104
TB-105
TB-106
WINCHESTER MRAC 104SJTGH
FCP # 1 CONTROL W10120
FCP # 2 CONTROL W10122
FCP # 3 CONTROL W10124
FCP # 4 CONTROL W10126
FCP # 5 CONTROL W10128
FCP # 6 CONTROL W10161
DISPLAY PROCESSOR
UNIVAC 1218
150' EACH
COMPUTER DATA W10019
COMPUTER DATA W10020
150' EACH
UNIVAC 308221
VERTICAL SYNC W10151 23'
HORIZONTAL SYNC W10152 23'
5800-
PRIME POWER
DRUM CABINET
10800
3.685 Mc CLOCK PULSES W10154 23'
FIELD PULSES W10153 23'
CHANNEL 1 VIDEO W10121
CHANNEL 2 VIDEO W10123
CHANNEL 3 VIDEO W10125
CHANNEL 4 VIDEO W10127
CHANNEL 5 VIDEO W10129
CHANNEL 6 VIDEO W10162
GRD

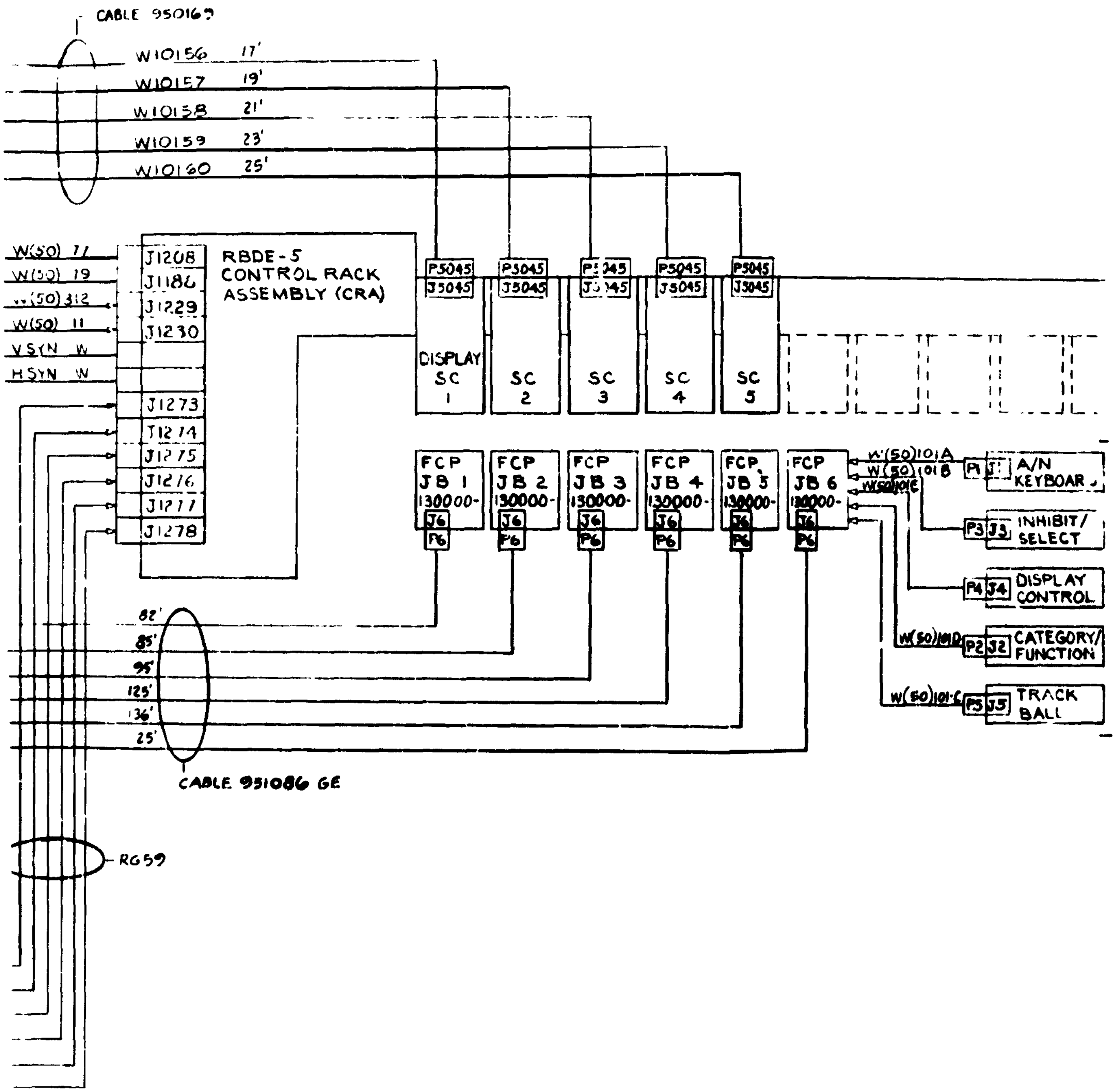


Figure 3-12. ARTS-ANG In

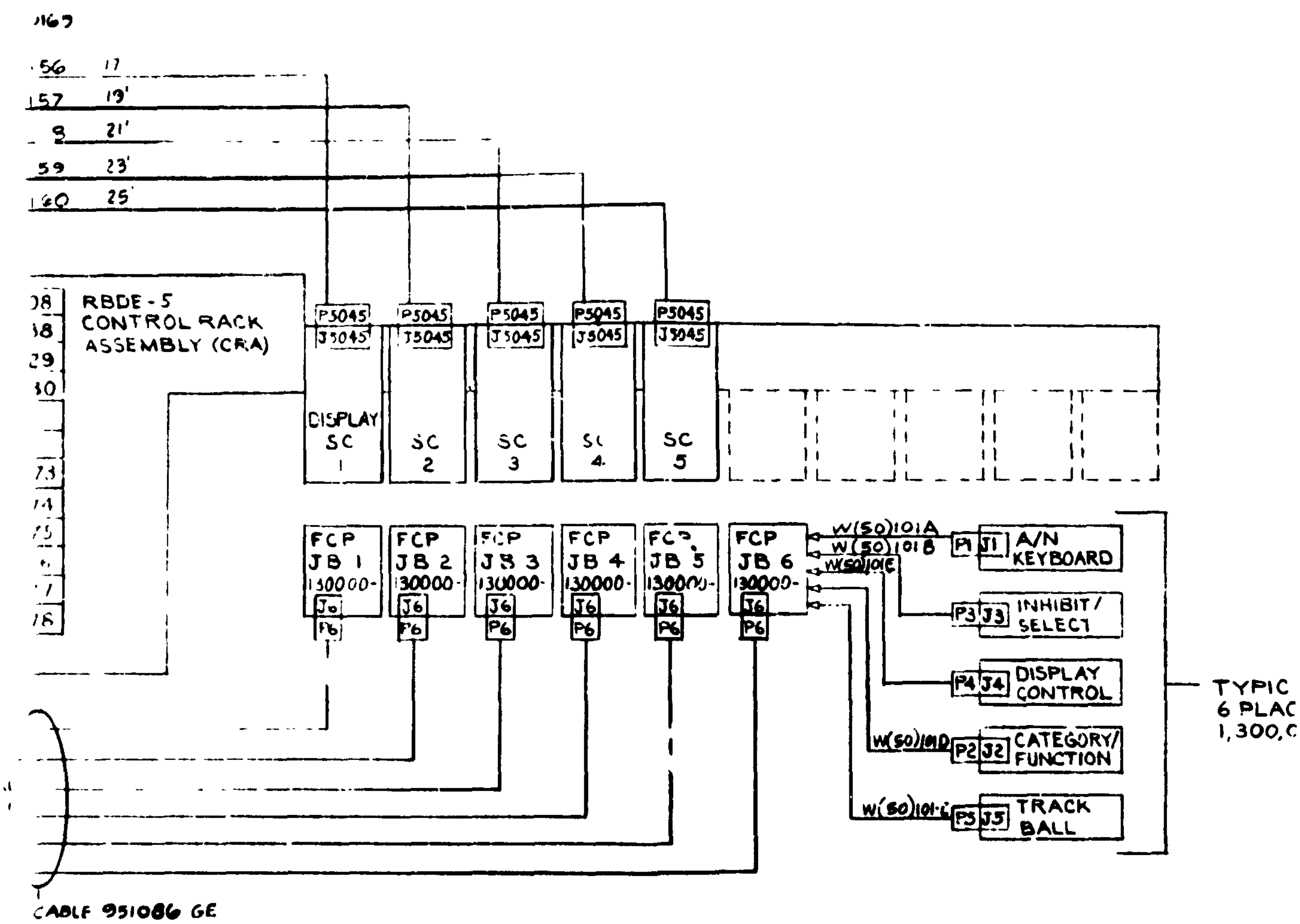
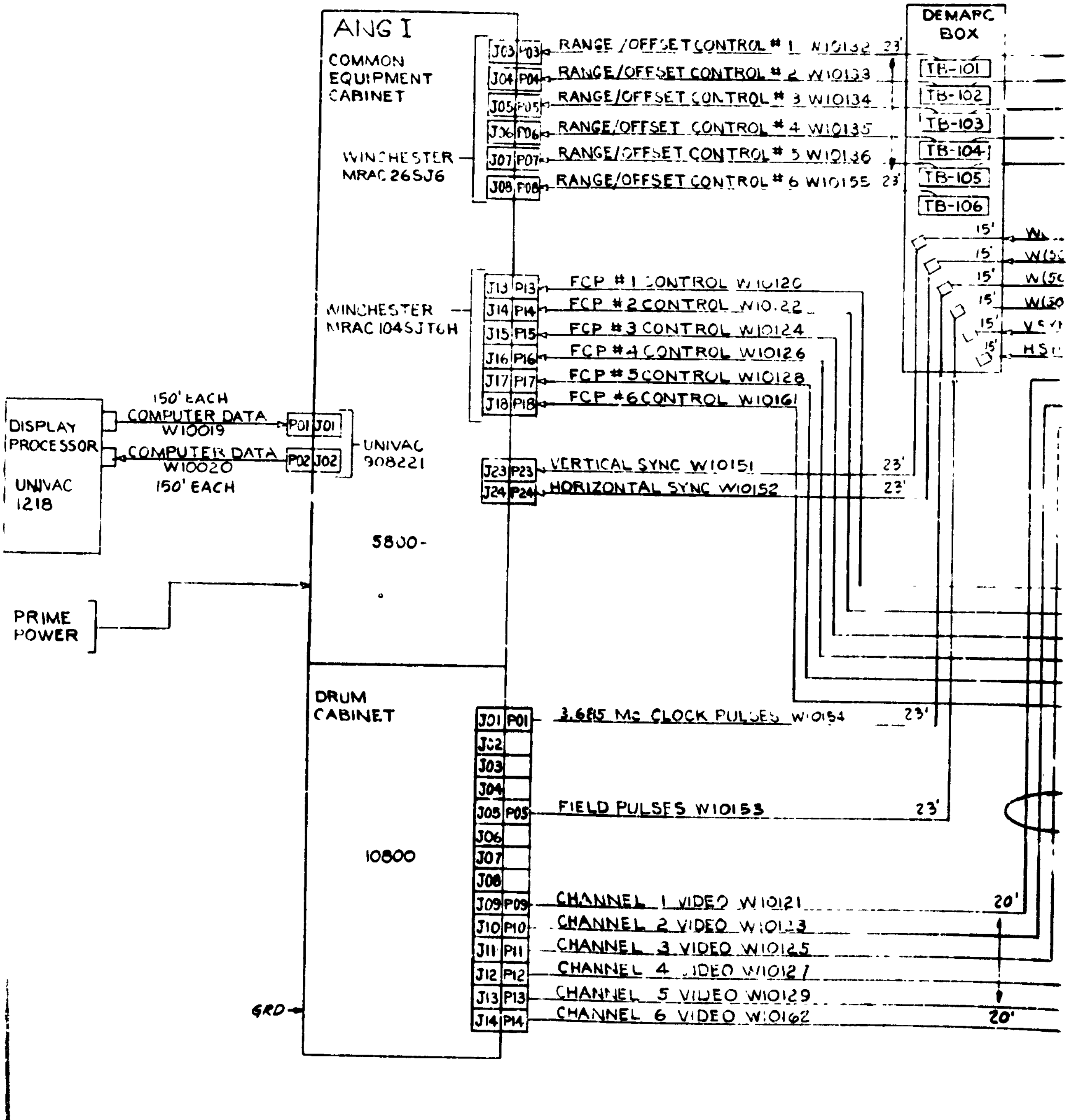
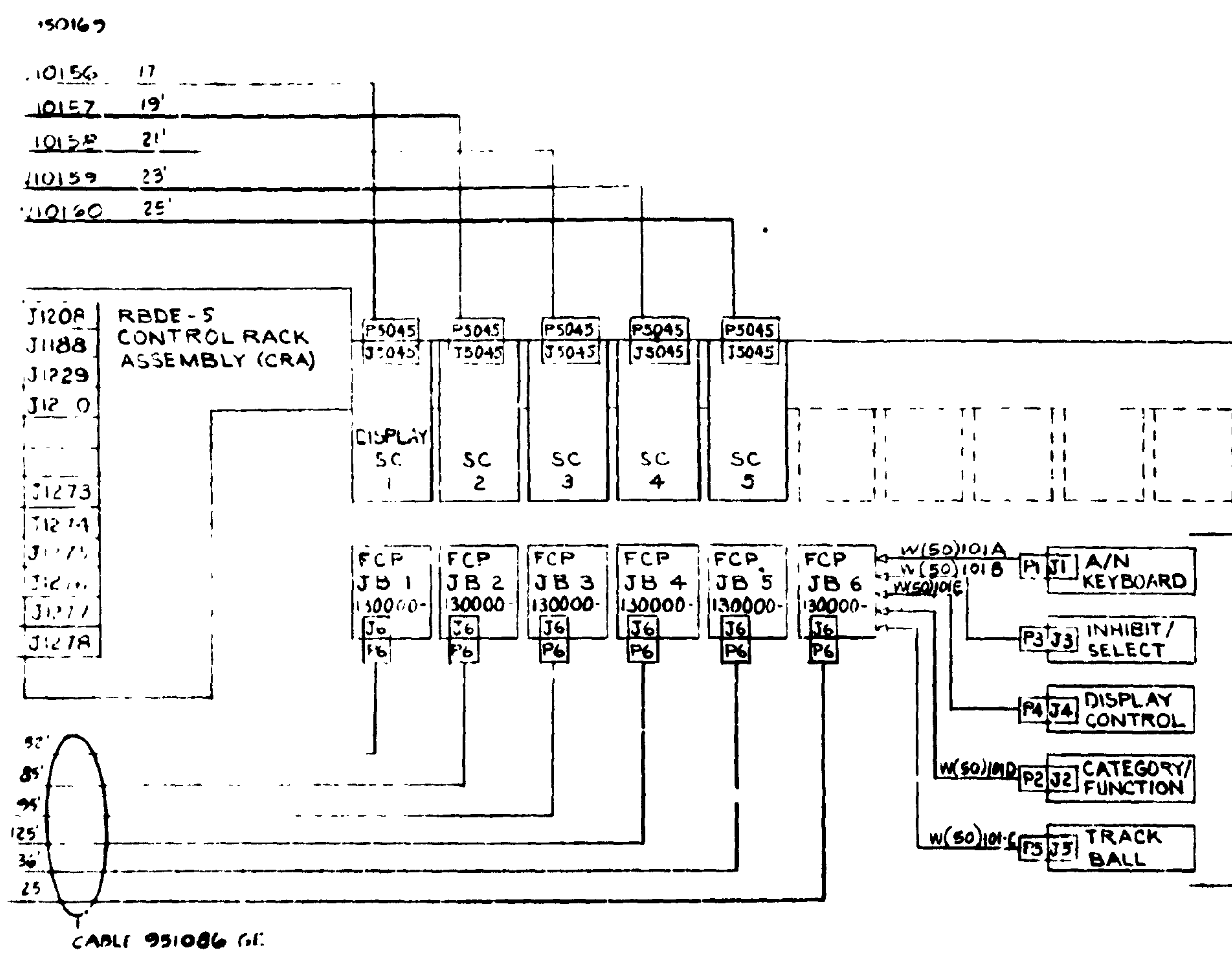


Figure 3-12. ARTS-ANG Interconnectior


ANG I
COMMON EQUIPMENT CABINET
WINCHESTER MRAC 26SJ6
WINCHESTER MRAC 104SJTGH
RANGE/OFFSET CONTROL #1 W10132 23'
RANGE/OFFSET CONTROL #2 W10133
RANGE/OFFSET CONTROL #3 W10134
RANGE/OFFSET CONTROL #4 W10135
RANGE/OFFSET CONTROL #5 W10136
RANGE/OFFSET CONTROL #6 W10155 23'
DEMARC BOX
TB-101
TB-102
TB-103
TB-104
TB-105
TB-106
FCP #1 CONTROL W10120
FCP #2 CONTROL W10122
FCP #3 CONTROL W10124
FCP #4 CONTROL W10126
FCP #5 CONTROL W10128
FCP #6 CONTROL W10161
DISPLAY PROCESSOR
UNIVAC 1218
150' EACH
COMPUTER DATA W10019
COMPUTER DATA W10020
150' EACH
UNIVAC 908221
VERTICAL SYNC W10151 23'
HORIZONTAL SYNC W10152 23'
5800-
PRIME POWER
DRUM CABINET
10800
3.685 Mc CLOCK PULSES W10154 23'
FIELD PULSES W10153 23'
CHANNEL 1 VIDEO W10121 20'
CHANNEL 2 VIDEO W10123
CHANNEL 3 VIDEO W10125
CHANNEL 4 VIDEO W10127
CHANNEL 5 VIDEO W10129
CHANNEL 6 VIDEO W10162 20'
GRD
A


150169
10156 17
10157 19'
10158 21'
10159 23'
10160 25'
J1208
J1188
J1229
RBDE-5
CONTROL RACK
ASSEMBLY (CRA)
J1273
P5045
J5045
DISPLAY SC 1
SC 2
SC 3
SC 4
SC 5
FCP JB 1 130000-
FCP JB 2 130000-
FCP JB 3 130000-
FCP JB 4 130000-
FCP JB 5 130000-
FCP JB 6 130000-
J6
P6
W(50)101A
W(50)101B
W(50)101E
W(50)101D
W(50)101C
P1 J1 A/N KEYBOARD
P3 J3 INHIBIT/SELECT
P4 J4 DISPLAY CONTROL
P2 J2 CATEGORY/FUNCTION
P5 J5 TRACK BALL
125'
36'
25
CABLE 951086

2659

B

Figure 3-12. ARTS-ANG Interconnections

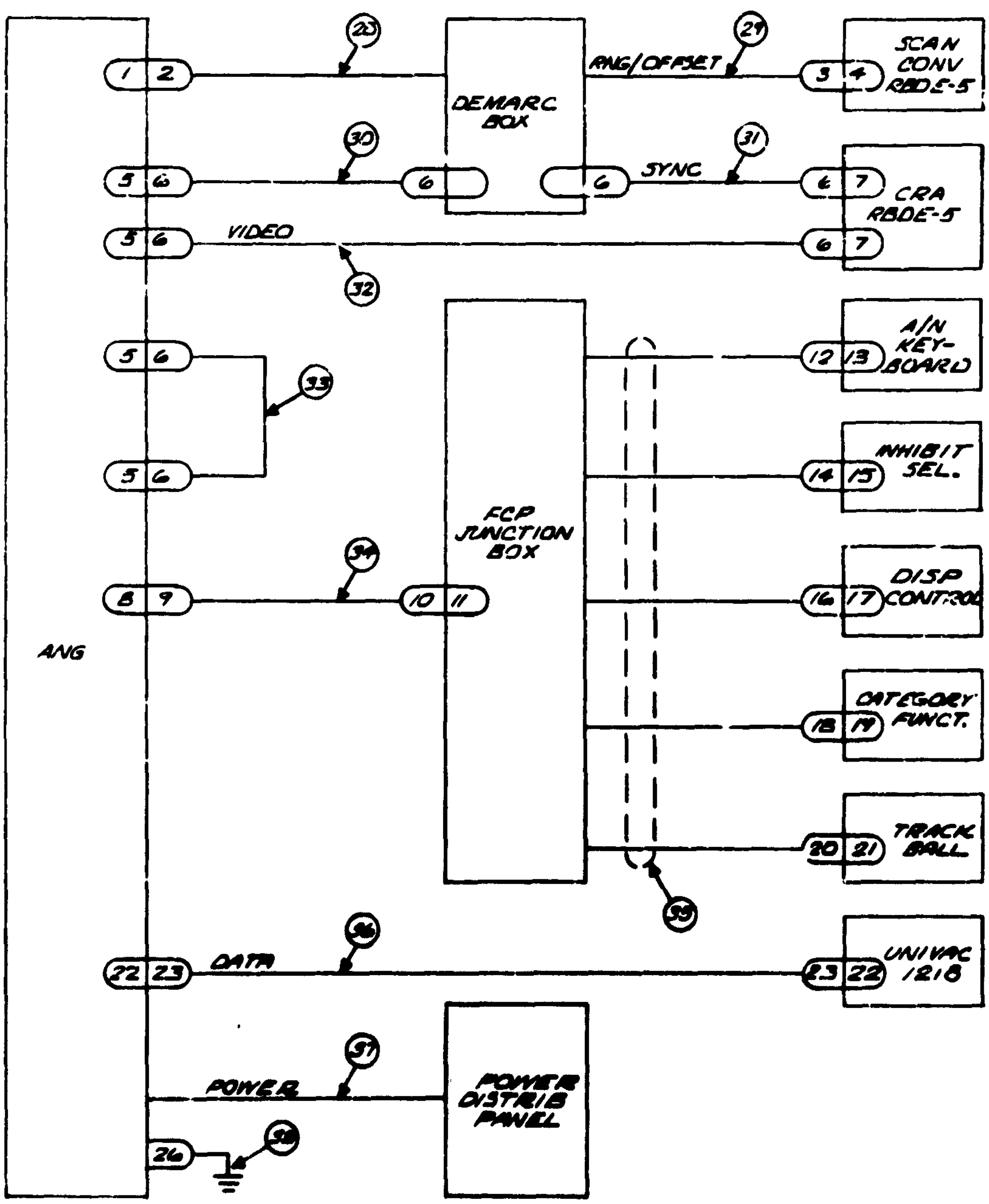


Figure 3-13. Parts Listing of ARTS-ANG Interconnection

are delivered from J1 of the ANG-1 Drum Cabinet to J1229 of CRA-1 via the "Demarc" box and coaxial cables W(50)311 and 311A. (RG-59/U with BNC connectors.) These "locking" clock pulses are effective only when the RBDE-5's SYNC INT/EXT switch is in the "EXT" position. The RBDE-5 synchronizer in CRA-2 counts down the clock pulses and provides subsystem horizontal and vertical Sync pulses of proper timing and duration. These sync pulses are returned to the ANG-1 Common Equipment cabinet (J24 and J23 respectively) from CRA-2 via the "Demarc" box and coaxial cables (W(50)179, 179A and W(50)177, 177A(RG-59/U with BNC connectors). To ensure synchronization of odd and even TV fields within the subsystem, TV "Field Pulses" (Index pulse) are sent from the ANG-1 Drum Cabinet (J5) via cables (W(50)311 and 311A (RG-59/U with BNC connectors) and the "Demarc" box to J1230 of CRA-2. These pulses are effective only when the RBDE-5 SYNC INT/EXT switch in CRA-2 is in the "EXT" position.

For servicing purposes, FAA will provide auxiliary Vertical and Horizontal Sync outputs at the "Demarc' box via coaxial cables W(M) and W(L) respectively.

f. Range/Offset

In order for ANG-1 to properly position its information on the display screens, it is necessary that it be able to periodically determine the range and sweep origin off-center operating condition of each RBDE-5 scan converter within the display subsystem. The most convenient and economical way to obtain this information is to sense the condition of the range select relays through the use of a previously unused contact in each relay, and to strobe the digital number representing the positions of the E-W and N-S off-center brush encoders in each scan converter. This method of obtaining the information requires a modification to each scan converter cabinet. Hazeltine provides the necessary kit and installation instructions.

The second range/off-center information for each scan converter will be read out into ANG-1 via contractor-furnished 24-conductor shielded cables (W(A) through (K) inclusive) and the "Demarc".

TABLE IX. CABLES AND CONNECTORS FOR ARTS-ANG

KEY	PART NUMBER	QTY
1	Winchester MRAC 26SJ6	6
2	Winchester XAC 26PC1306	6
3	MS3106B24-28P	6
4	MS3102A24-28S	5
5	AMP2-329458-1	14
6	AMP2-329445-1	24
7	Presently Installed	12
8	Winchester MRAC 104SJ6	6
9	Winchester XAC 104PC1306	6
10	Winchester MRAC 104SJTC6H	6
11	Winchester XAC 104PF2006	6
12	Winchester MRAC 34SJTC6H	6
13	Winchester XAC 34PF2006	6
14	Winchester MRAC 14SJTC6H	6
15	Winchester XAC 14PF2006	6
16	Winchester MRAC 26SJTC6H	6
17	Winchester XAC 26PF2006	6
18	Winchester MRAC 66SJTC6H	6
19	Winchester XAC 66PF2006	6
20	ELCO: 00.6014.015.928.002	6
21	ELCO. 00.6015.015.000.000	6
22	Univac 950169	4
23	Univac 259056-03	4
24		
25		
26	Bulldog Electric #3041	1
27		
28	HED 950169	6
29	HED 950169	6
30	RG-59( )/U	4
31	RG-59( )/U	6
32	RG-59( )/U	6
33	RG-59( )/U	2
34	HED Ass'y 951086	6
35	HED Ass'y 103820	6
36	Univac 5192	2
37		
38	#4 AWG	

g. Display Processor (Univac 1218) Data Lines

Data exchange between ANG-1 and the Univac 1218 Display Processor is via two special Univac cables (Cable W10019 to ANG-1 and Cable W10020 from ANG-1.) Both cables are contractor supplied.

E. Test Procedures

1. Diagnostic Routines

The diagnostic routines needed to check out the system provide two basic inputs: test codes and system simulation codes. Test codes allow test engineers to trace signal flow, while system simulation codes are realistic inputs to check out the actual operating system.

In order to provide the input flexibility needed, a "Universal-Output" routine has been written. The routine is capable of accepting inputs from up to ten (10) FCP consoles or from the U-1218 I/O typewriter, and displaying outputs (system inputs) at the proper console. Thus test codes, display-coordinate codes, and radar-coordinate codes may be transmitted to and from the system readily.

Test codes are used to check out pieces of system equipment using any desired combination of bits, which will be repeated as long as the test engineer needs the message. Display coordinates are checked by causing plus (+) signs to be displayed at nine (9) points of an RBDE-5 grating bar display. The nine points are located as follows: at each corner, at each midpoint, and at the center of the display. (Figure 3-14)

Radar coordinates are checked under all of the following conditions:

(a) Grating bar check as above.

(b) Range ring check at all range settings.

  (1) Concentric range circles about center.

  (2) Concentric range circles about the N, NE, E, SE, S, SW, W and NW edges of the display.

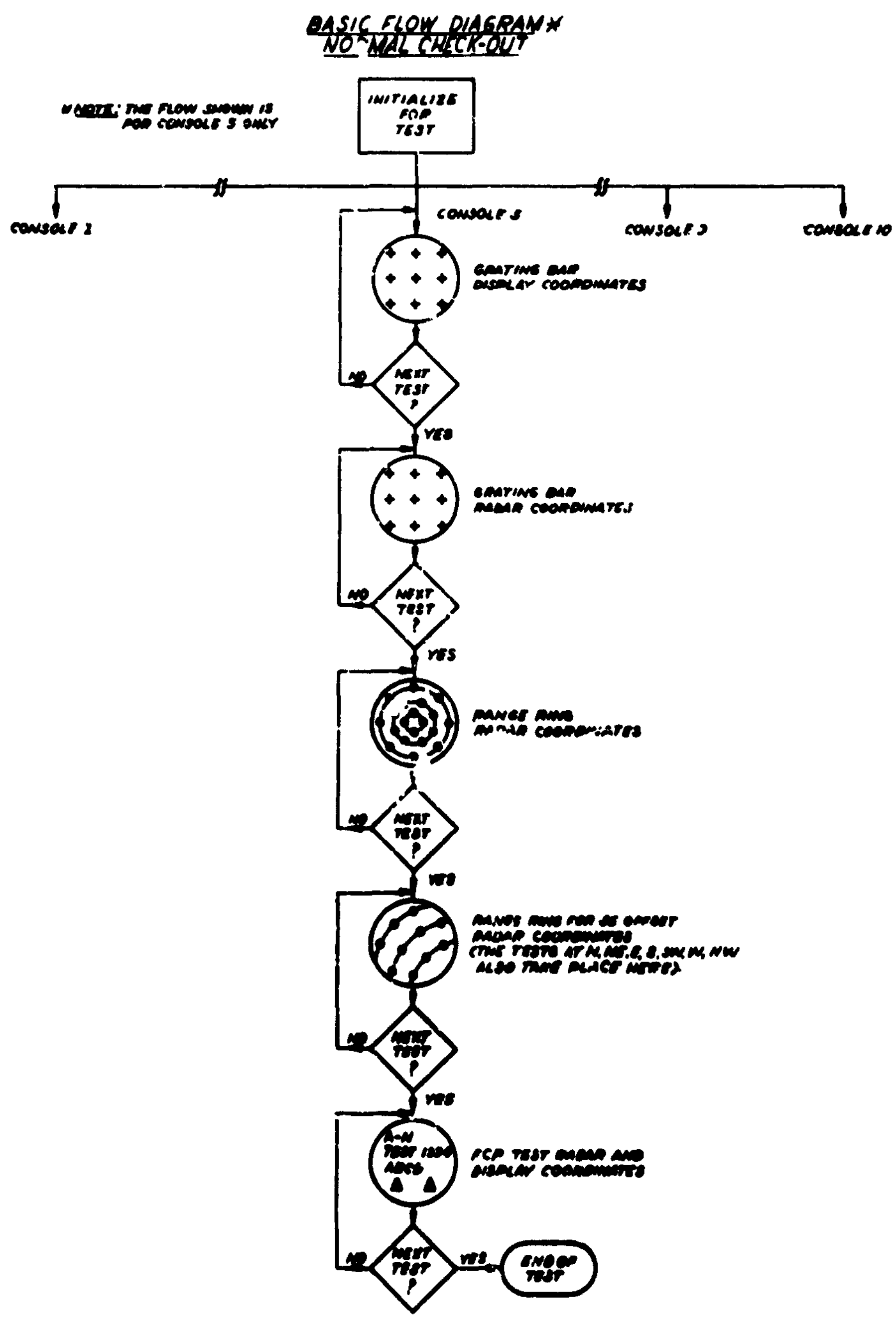


Figure 3-14. Flow Diagram, Normal Check-Out

The quick-look feature may be used to check range ring overlap between displays to ensure complete system continuity.

Two-way communications between all FCP consoles and the 1218 will be checked for the transmittal of tracking and A/N information. The FCP operator places his slew dot over a target displayed on his screen and depresses his track-ball enter button. If the system is operating properly, a target symbol will be placed around the target. This procedure is followed for several targets, using radar and display coordinates. A/N communication is checked by displaying all messages that the FCP operator enters.

Each console can be checked out independently. This is accomplished by having the same test patterns transmitted independently to all displays rather than one test pattern transmitted simultaneously to all displays.

2. Magnetic Drum Tests

The magnetic drum, which had been ordered from Bryant Corporation under Hazeltine Specification 1-TD-7282, was delivered to the Greenlawn laboratory in the middle of January 1964. After delivery, the drum was inspected and tested for compliance with Hazeltine's specification to the extent listed below.

Sec. 3.1 - Track layout has been inspected and is satisfactory.

Sec. 3.2 - Magnetic heads have been inspected for number and placement.

Sec. 3.4 - A timing track was tested with the following results:

3.4.1 Bits per track - 20,475

3.4.2 Pulse repetition frequency - 614.25 Kc

NOTE: This frequency is multiplied by six to obtain the 3.6855 Mc required by the RBDE-5 for sync.

3.4.3 Pulse density - 352 bits/inch

NOTE: This is the highest frequency required. A separate timing track was generated to supply pulses to the low speed synchronizer. These pulses are directly related to the 18.4275 Mc video output rate.

4.0 Mechanical details have been inspected and are satisfactory. The noise level is within the specification.

5.0 The drive system has been tested with the exception of the ±30% voltage variation. Time to reach synchronous speed was 3.5 minutes.

A test jig was developed for writing highly accurate timing pulses on the drum. The following additional timing tracks were recorded for use with the ANG system:

1. Index pulse - one per revolution.

2. Horizontal Test Trigger - occurs at leading edge of horizontal sync pulse.

3. Vertical Test Trigger - occurs at leading edge of vertical sync pulse.

4. Low Speed Sync - origin of t_o pulse to the low speed synchronizer.

5. Delayed Vertical Sync - starts on leading edge of 9th Horizontal Trigger after Vertical Sync. (Used by character generator control).

A test of the capability of the magnetic drum to store and read out data through the video generator circuits to the RBDE-5 display was made. In this test groups of 16-bit patterns were stored on every 16th bit position of the magnetic drum. When read out to the video generator, the bit patterns thus stored, will fall directly under one another in a continuous column from the top to the bottom of the TV raster. A solid bar of "ones", 16 bits wide was first stored and displayed. Then, alternating ones and

zeros were stored on the drum to display a series of vertical lines, separated by one-dot spaces. The stability and linearity of these lines were improved during the test by modifications which improved the video generator circuit timing. After the linearity of the lines had been proven, bit patterns were stored which would read out alpha-numeric characters and symbols. After some difficulty with the interlace of the TV synchronizing system, characters with excellent quality and stability were produced.

SECTION IV

REVIEW AND RESULTS OF POFA TESTS

The purpose of the POFA (Programmed Operation Functional Appraisal) test routine is to exercise all of ANG's functional circuits including those associated with the operator controls. These tests serve as acceptance tests and comprise the regular maintenance routine for checkout of the ANG's. ANG-1 and ANG-2 have passed all POFA tests.

This section describes the tests which make up the POFA routine and the purpose of each test. Photographs which were taken of the RBDE-5 TV display during POFA testing of ANG are included with certain test descriptions. Each test routine applies to both ANG-1 and ANG-2 except where noted.

1. Character Repertory Test

The purpose of this test is to demonstrate the ability of the ANG to:

(a) Generate all characters.

2. BOF/EOF Test

The purpose of this test is to demonstrate the ability of the ANG to:

(a) Interpret the Beginning of Data and End of Data External Function signals, see Figures 4-1, 4-2, and 4-3.

3. Display Coordinate Test

This test demonstrates the ability of ANG to:

(a) Correctly interpret all display coordinate positioning bits.

(b) Correctly interpret that display coordinates are selected when the Display/Radar Coordinate Indicator Bit is a logical zero.

(c) Be immune to the RBDE-5 range switch setting while operating in the display coordinates.

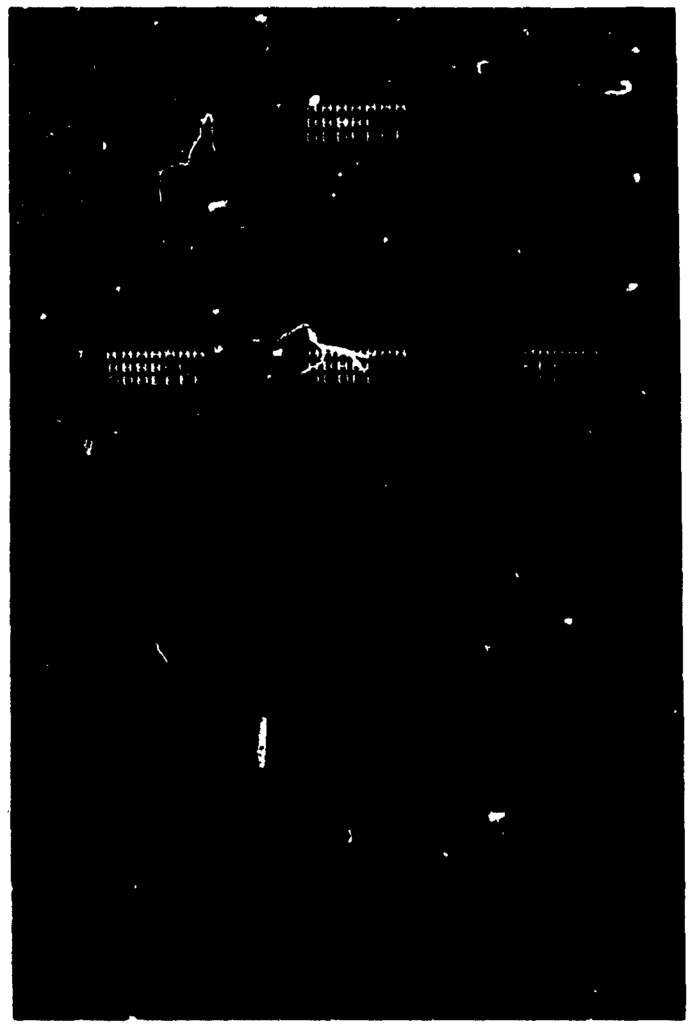


Figure 4-1. BOF and EOF Test 1

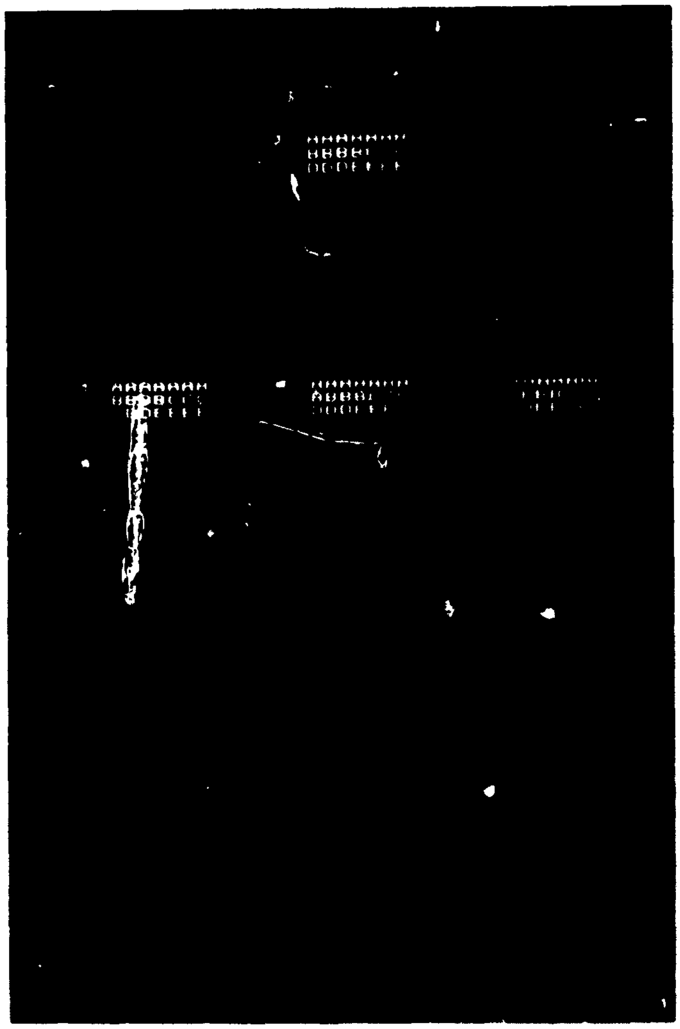


Figure 4-2. BOF and EOF Test 2

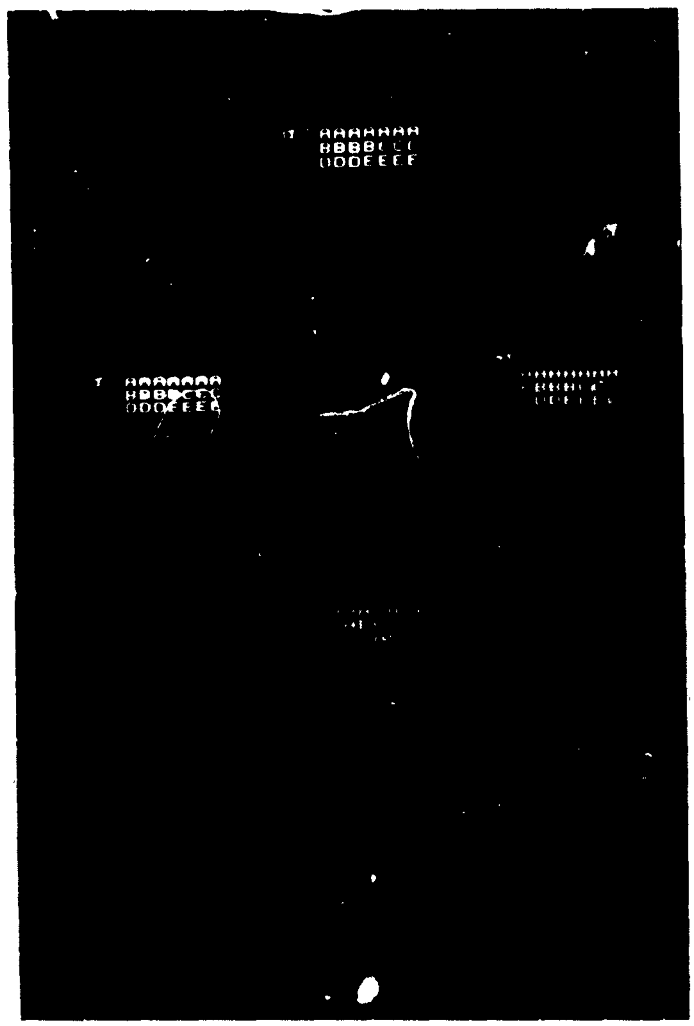


Figure 4-3. BOF and EOF Test 3

(d) Be immune to the RBDE-5 off-centering control setting when operating in display coordinates.

4. Radar Coordinate Test

This test demonstrates ANG's ability to:

(a) Correctly interpret all X and Y radar coordinate positioning bits.

(b) Correctly interpret that radar coordinates are selected when the Display/Radar Coordinate Indicator bit is a logical one.

(c) Be affected by the RBDE-5 range switch setting.

(d) Be affected by the RBDE-5 off-centering control setting.

5. Route Segment Test

This test checks ANG's ability to:

(a) Generate route segments - see Figures 4-4 and 4-5.

(b) Correctly determine that the X and Y coordinate components are interpreted as a route segment when the Route Segment/Velocity Indicator bit is a logical zero.

(c) Display correctly interpreted route segments when the Print/Non-Print bit is a logical zero.

(d) Display route segments which are not affected by the Vector-Time switch.

6. Vector Velocity Test

This test checks ANG's ability to:

(a) Generate velocity vectors, see Figure 4-6.

(b) Correctly interpret that the X and Y Coordinate Components are for a velocity vector when the Route Segment/Velocity bit is a logical one.

(c) Correctly compute the velocity vector magnitude as a function of range and time.

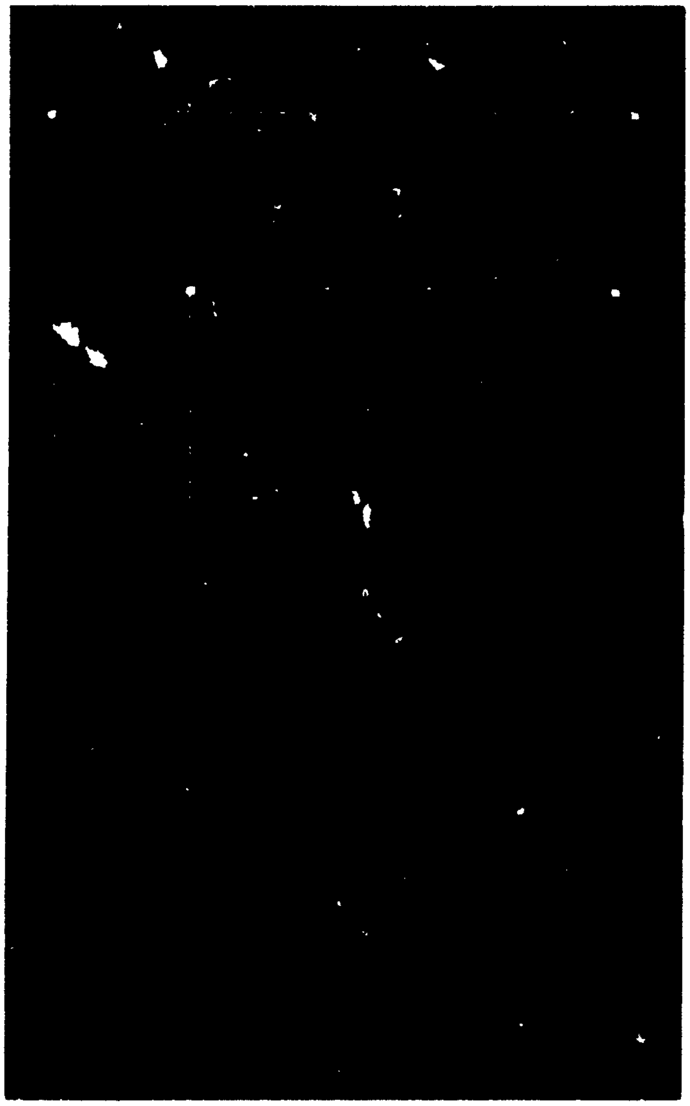


Figure 4-4. Route Segment Test Pattern

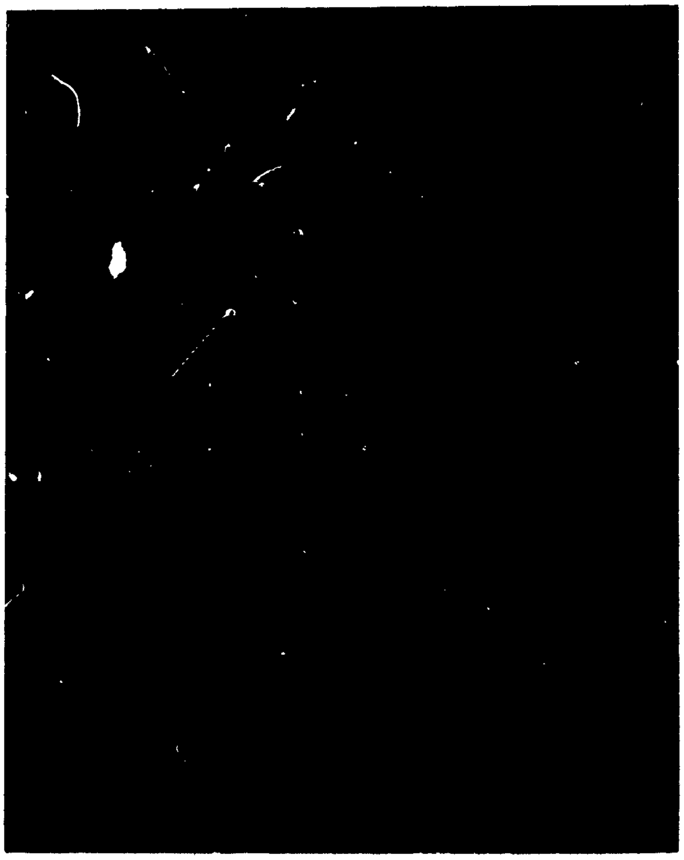


Figure 4-5. Route Segment Test Pattern

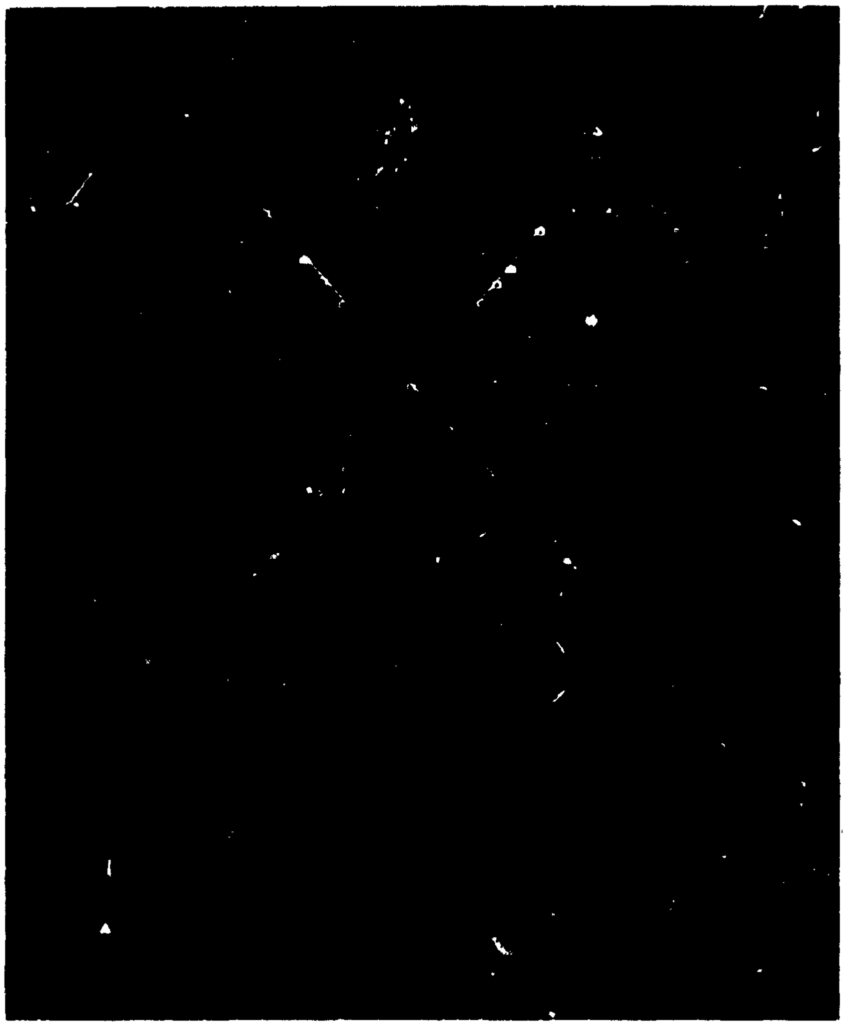


Figure 4-6. Vector Velocity Test

7. Alpha-Numerics Format Test

This test checks ANG's ability to:

(a) Display track formats together with bars and leaders, see Figure 4-7.

(b) Automatically reposition within the display area any format which would be either partially or totally lost because it is positioned on the edge of the display area.

(c) Maintain reasonable character legibility in the overlapped portion of two formats.

(d) Generate leaders whose lengths are in accordance with the leader OFFSET control and which do not deviate from a straight line by more than 5% of their displayed length.

(e) Correctly interpret that the format should be offset when the offset non-offset bit is a logical one, see Figure 4-8.

8. Field Select/Quick Look/Intensity Controls Test

This test checks ANG's ability to:

(a) Blank all display data addressed in radar coordinates by means of appropriate field select switches; the field select switches shall not affect display data addressed in display coordinates, see Figure 4-9.

(b) Correctly interpret that the field select switches have no effect on the display when the Field/Select/Non-Field Select Control bit is a logical zero and that the field select switches do affect the track format for the display when the Field Select/Non-Field Select Control bit is a logical one.

(c) Select and display data which is assigned to another console via the quick look function.

(d) Control the intensity of characters on the RBDE-5 via the intensity control.

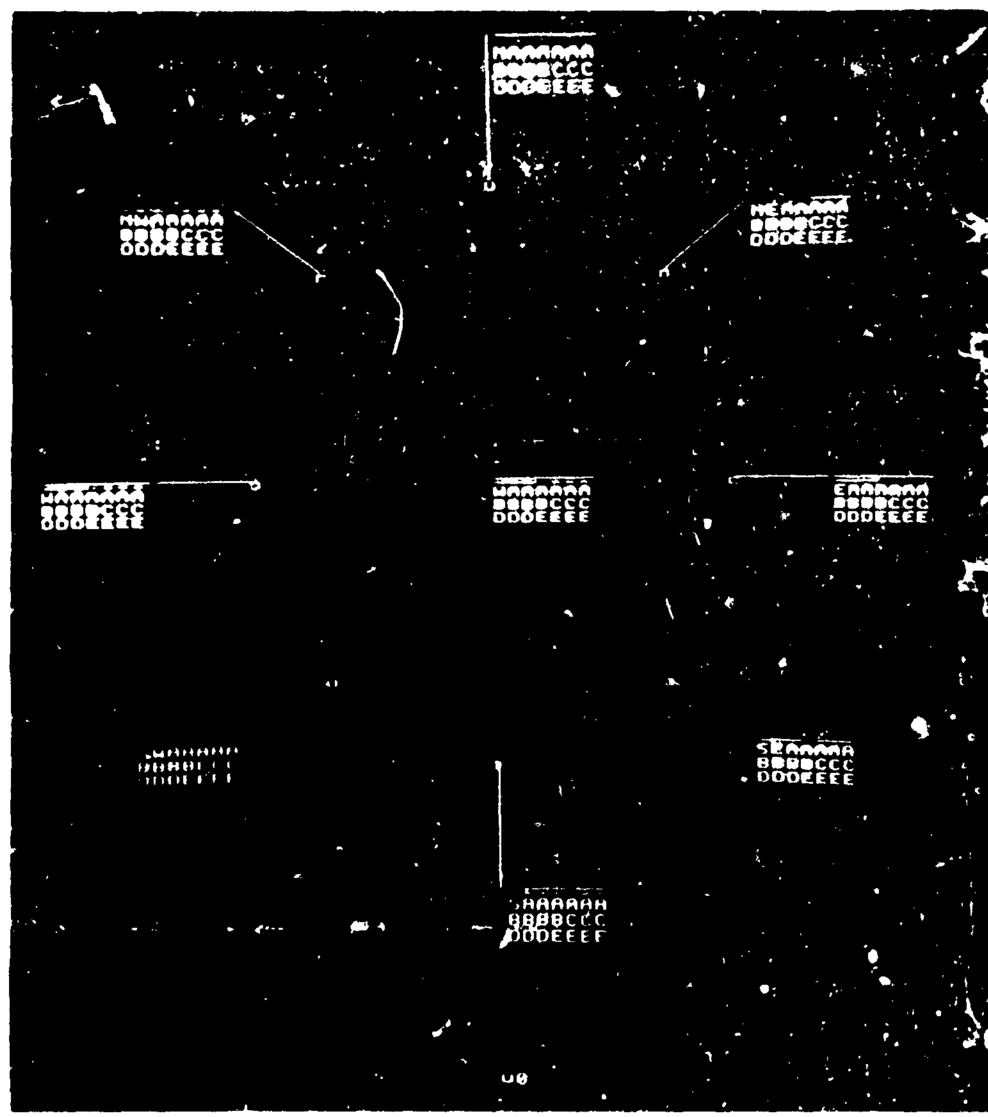


Figure 4-7 A-N Format Test Pattern

Figure 4-8 A-N Offset/Non-Offset Test

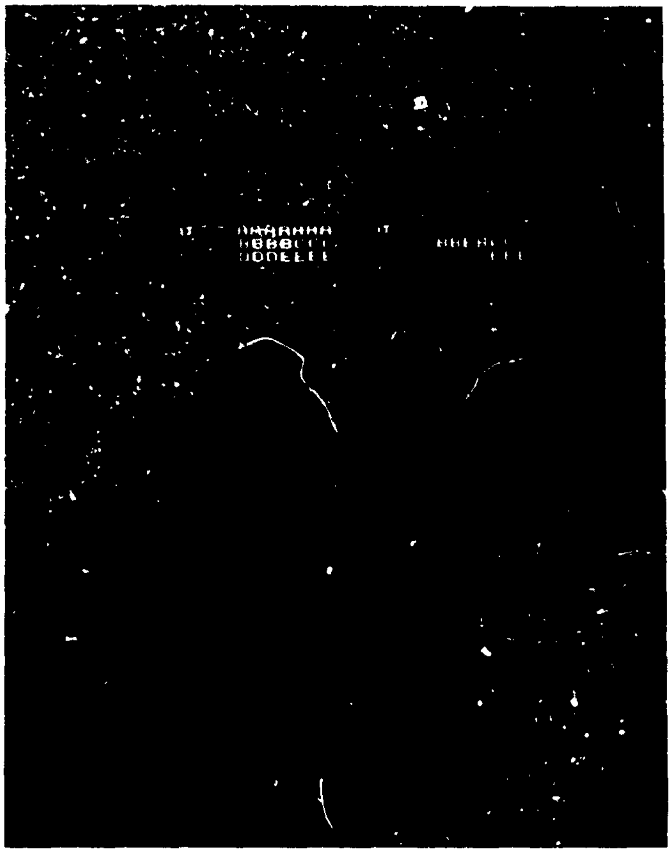


Figure 4-9. Field Select Test Pattern

9. Display Capacity Test

This test checks ANG's ability to:

(a) Handle the maximum number of track formats, see Figure 4-10.

(b) Handle the maximum amount of display data.

(c) Display straight rows and columns of characters, see Figure 4-11.

10. FCP Keyboard Entry Test

This test checks ANG's ability to:

(a) Generate the proper codes for the category, function and character entries, see Figures 4-12, 4-13, and 4-14.

(b) Generate a proper validity message display (characters only) for each entry and be capable of positioning it at each of the four possible locations, see Figure 4-15.

11. Slew Dot Test

This test checks ANG's ability to:

(a) Generate and transmit accurate slew dot X-Y coordinate data to the computer.

(b) Generate associated slew dot video on the display.

(c) Reposition slew dot to center of the display after the entry button is activated.

(d) Reposition slew dot to the opposite edge of the display with respect to the edge at which the operator moves it off the display area.

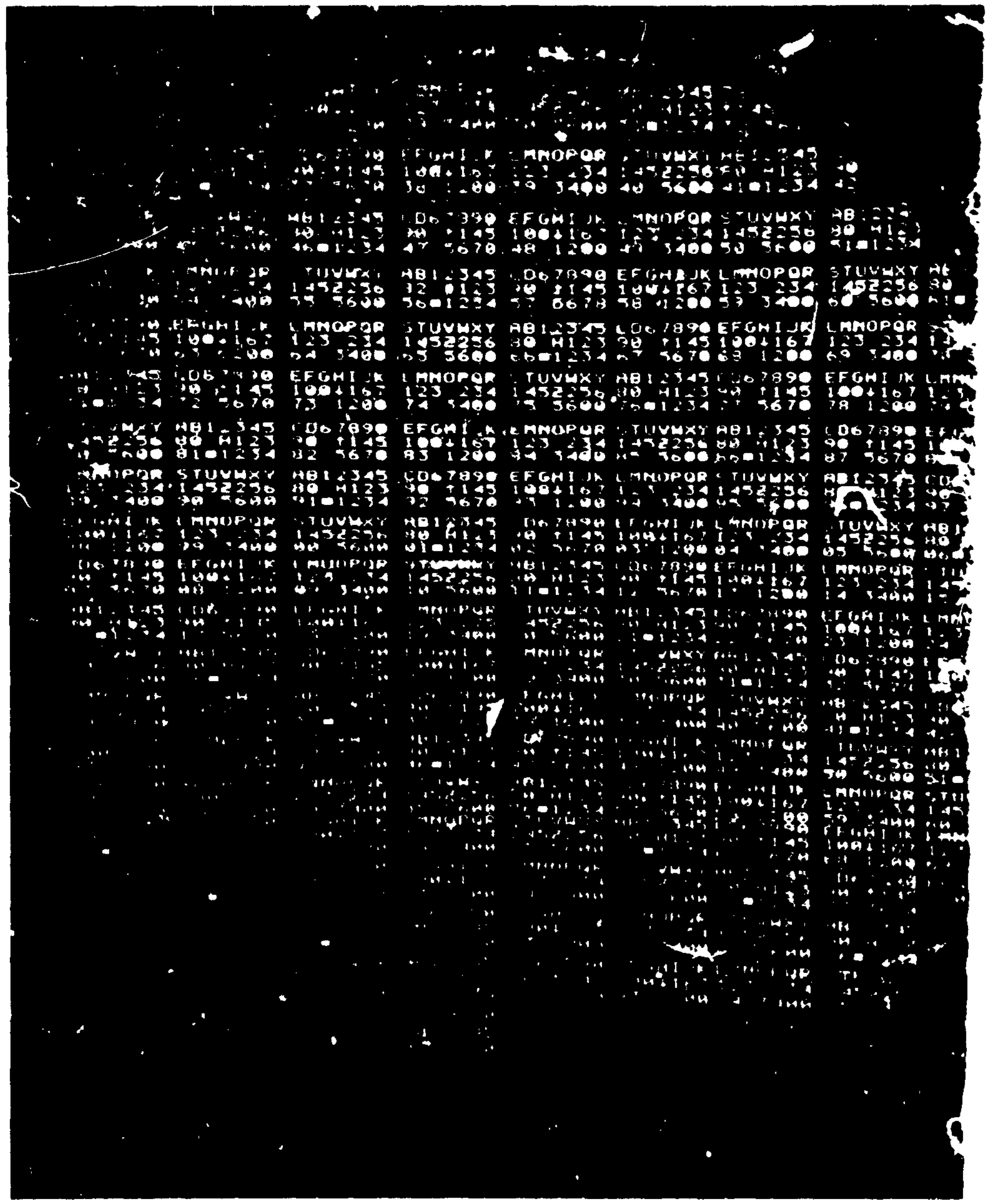


Figure 4-10. Display Capacity Test

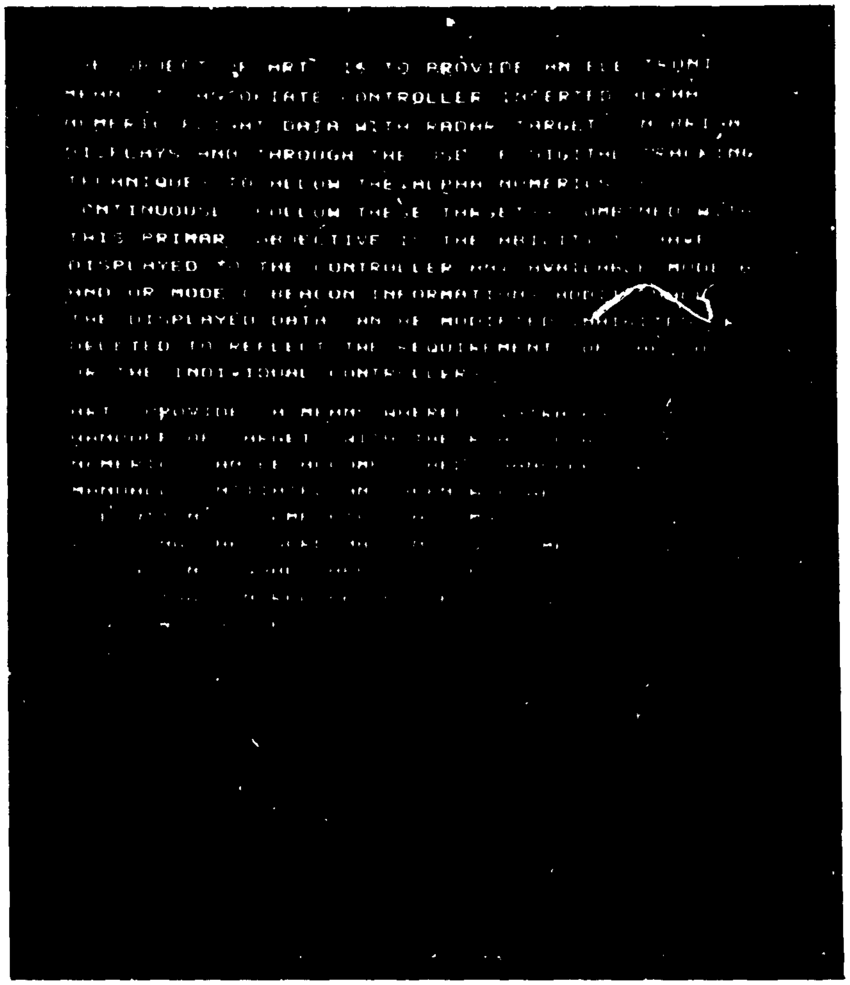


Figure 4-11. Page Print

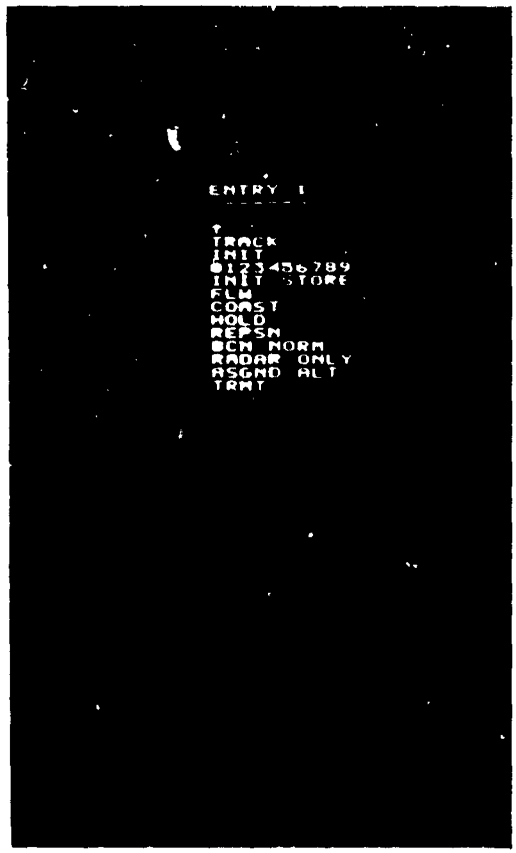


Figure 4-12. FCP Entry 1 Test

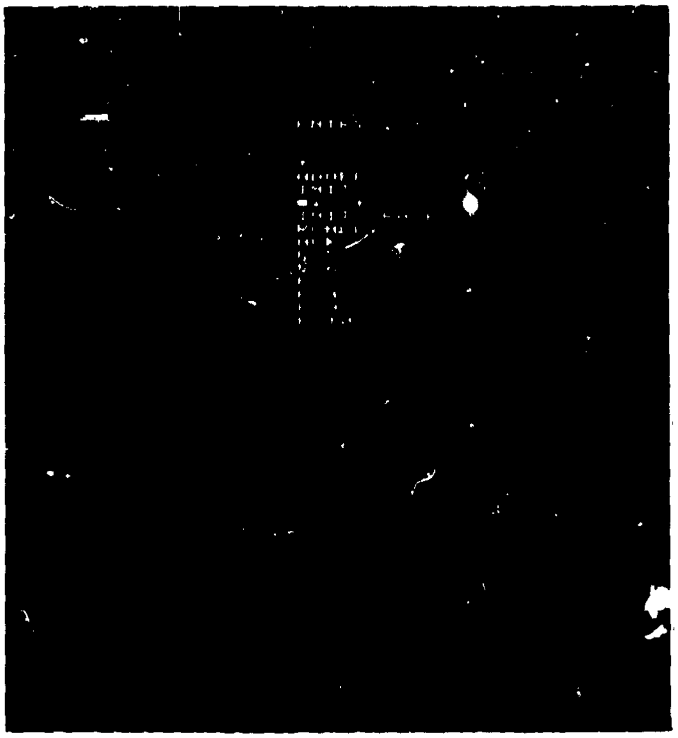


Figure 4-13. FCP Entry 2 Test

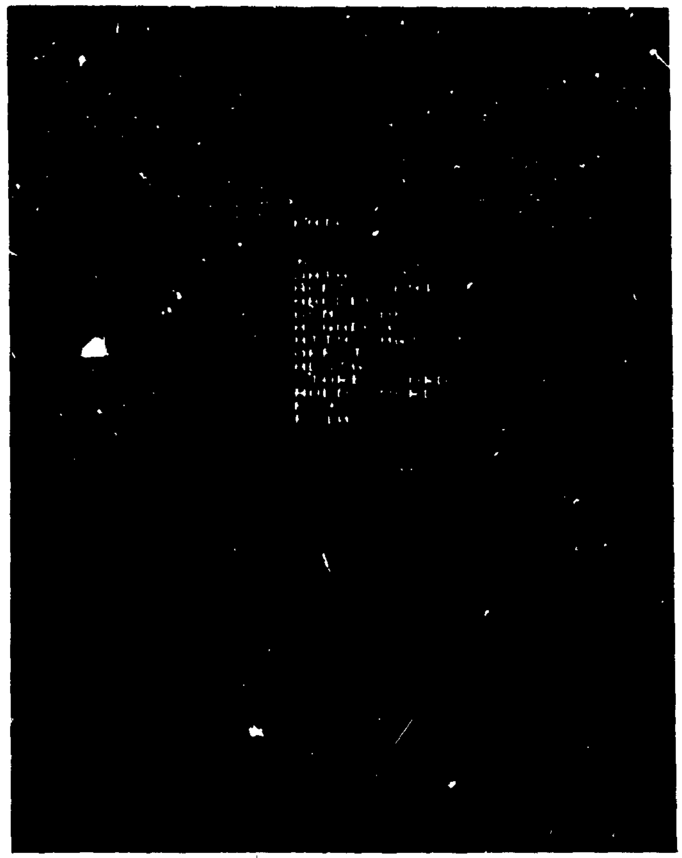


Figure 4-14. FCP Entry 3 Test

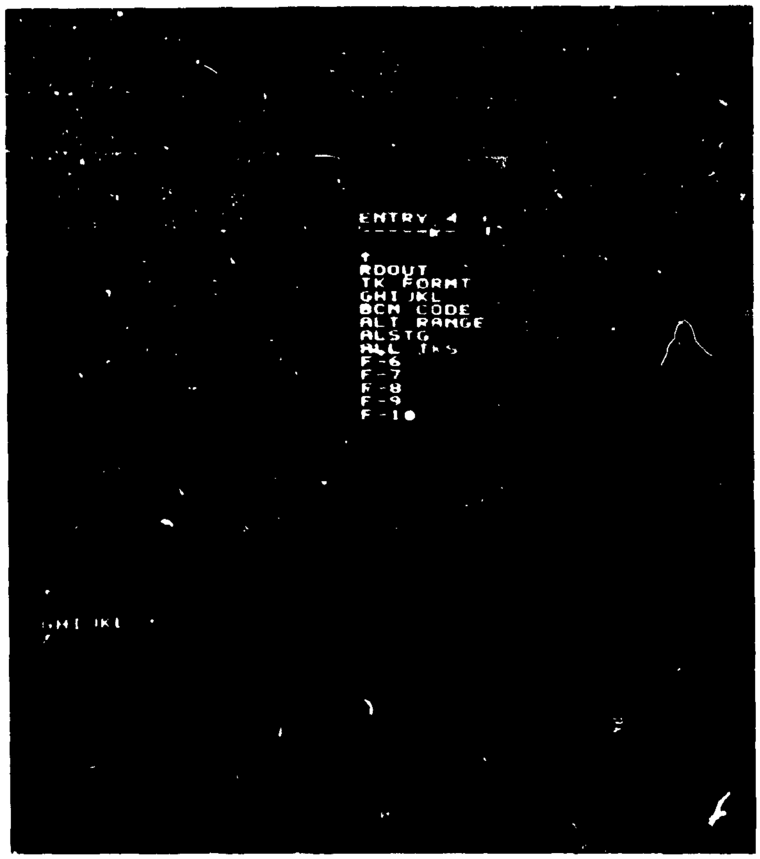


Figure 4-15. FCP Entry 4 Test

12. Input/Output Buffer and Parity Test

This test checks ANG's ability to:

(a) Process correctly both an FCP keyboard entry (message to 1218) and an input message (from the 1218) on an interlaced basis.

(b) Correctly respond to each of the external function parity codes.

13. Vertical and Horizontal Sync Test

This test demonstrates ANG's ability to provide both itself and the RBDE-5 with Vertical and Horizontal Sync signals recorded on the drum in a manner which permits proper system operation.

14. Moving Target Test

This test demonstrates ANG's ability to display legible moving targets (with no smearing).

15. Beacon Test

This test demonstrates ANG's ability to:

(a) Correctly interpret and respond to beacon code.

(b) Select and display data which is assigned to other consoles operating with the same beacon via the quick look function (ANG-2 only).

SECTION V

CONCLUSIONS

1. The development and installation of a six and ten channel Alpha-Numeric Generator in the ARTS and SPAN air Traffic Control Systems, respectively, was completed successfully.

2. The Alpha Numeric Generator (ANG) utilizing TV techniques provides a practical means of electronically labelling aircraft on air traffic controllers' displays with alpha-numeric symbols and lines denoting aircraft identity, altitude, vector speed, and other data. High quality displays of data are provided; the letters, numbers, symbols, and lines are sharp and clear and easily used by air traffic controllers.

3. The basic method in the Hazeltine ANG of using a common equipment to form different TV pictures for many displays and a drum to refresh all of the displays at TV frame rates has been shown to be successful.

4. The flexibility and very large functional capability of the ANG make it a logical choice for servicing larger and more complex air traffic control centers.

5. The use of the ANG in the ARTS and SPAN systems makes possible increased operating efficiency of air traffic controllers by automating manual functions and reducing the amount of communications needed with pilots of controlled aircraft.

6. Particular functional capabilities of the ANG make possible increased safety of air travel by enabling air traffic controllers to readily predict potential future aircraft conflicts (vector generation, quick look functions, etc.) and to minimize possible controller errors in identification and location of aircraft (automatic tracking, semi-automatic handoff, etc.). The ANG also provides operator controls to enable repositioning and selective deletion of displayed data; this permits air traffic control to function properly in a dense environment.

7. One characteristic of ANG which proved undesirable was the momentary blinking of displayed alpha numerics, occurring each time a display was updated. This was subsequently corrected by the installation of improved drum read amplifiers, so that the ANG presently provides flicker-free displays of alpha numeric data.

END